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BULLETIN No. 138

The Economic Biology of Some Australian Clupeoid Fish

(Division of Fisheries—Report No. 6)

By

M. BLACKBURN, M.Sc.

MELBOURNE, 1941

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FOREWORD.

Taking the commercial fisheries of the world as a whole, it is safe to say that the fishes of the suborder Clupeoidei, including as it does such valuable types as the herrings, pilchards, sardines, sprats, and anchovies, are, taken together, second to none in importance; nevertheless, despite the fact that this group has long been known to be well represented in Australian waters, no serious attempt has ever been made to base a fishery upon it.

It was therefore felt necessary to make a consideration of this group one of the primary objectives of the investigational programme of the Fisheries Division, and this part of the work was placed mainly in charge of the author of this paper, which represents the first progress report of results. The conclusions are naturally very far from representing a complete statement upon the economic biology of the group, but many new facts are brought to light.

It is hoped that this paper will find its way into the hands of many of those who are in a position to co-operate in future work by supplying accurate representative information about these fishes, and that it will impress upon them the desirability of doing so. With this end in view a key for the identification of the species known from the temperate waters of Australia is appended; it is hoped that it will be found useful.

H. THOMPSON,
Chief, Division of Fisheries.

Cronulla,
New South Wales.

War time economy requires reduction in the Council's expenditure on publication. It is hoped that the adoption of the photo-lithographic process will be for a brief period only.

S U M M A R Y.

Studies have been made on seven species of clupeoid fish from the seas of south-eastern Australia, viz. the pilchard, southern herring, sprat, sandy sprat, blue sprat, maray, and anchovy.

1. The pilchard is typically a fish of the offshore and gulf waters, except perhaps at some young stages. There seem to be two separate population centres, one, consisting of mainly winter-spawning fish, occurring in the waters of New South Wales and southern Queensland, and the other, consisting of mainly summer or autumn-spawning fish, occurring in the waters of Victoria, South Australia, and possibly Tasmania. The fish tend to shoal at the surface in the spawning seasons; at other times they are probably present in the same waters but deeper down. They are rather small by comparison with many related species in other seas. The oil content is low except between spawning seasons.

2. The southern herring and the blue and sandy sprats are typical inhabitants of the inshore waters, and it is likely that they remain in them at all seasons. The two former have spawning seasons in the summer, while some spawning of the latter apparently occurs in both the summer and winter. The two latter species are small and apparently of low oil content, that of the blue sprat being higher, however. The herring is larger, but is also of low oil content.

3. The anchovy inhabits both the offshore and inshore waters. Although the data are somewhat incomplete, it seems probable that it is to be found to some extent at all seasons in at least some of the waters of New South Wales, Victoria, and Tasmania. The spawning seasons are not completely known, but seem to differ in different regions. The fish do not appear to form surface shoals to as marked an extent as the pilchard. They are mostly intermediate in size between the pilchards and the blue and sandy sprats, and their oil content is about the same as that of the two latter species. The eggs and larvae are described.

4. It is not clear whether the maray and sprat are to be regarded as more typically fish of the offshore or the inshore waters; apparently they may occur in either. Due

to lack of information and material, only very tentative conclusions can be drawn about these species, which are of medium size. The larvae of the maray are described.

5. Fishing experiments with the lampara net by day, when the fish most often shoal at the surface, have proved very disappointing, although somewhat better results have been obtained with this type of gear by night. Other types of surface seines (purse seine, and modifications of it) of the proper mesh size might be more useful and are shortly to be tested. Drift nets should also make moderate catches.

6. The possibility of basing an oil and meal reduction industry on any of these species does not appear promising, owing mainly to their low oil content (at least at the time when they are most abundant), and the difficulty of catching them in large enough quantities. Most of them would, however, be suitable for canning and/or curing, or for meal alone, and such types of industry could probably be assured of moderate steady supplies based on offshore fishing with surface seines and drift nets, possibly supplemented by inshore beach-seine and trap fishing. Regarding live-bait, the pilchard and anchovy, at least, appear to be suitable and available, and it will probably be possible to take them for this purpose in surface seine nets.

The Economic Biology of Some Australian Clupeoid Fish

I. INTRODUCTION.

1. Objects of Inquiry.

Generally speaking, a programme of research undertaken for the direct purpose of determining the economic possibilities of a group of fishes must be concerned with investigations along five main lines, as follows:-

(a) Systematic classification and definition of the components of the group.

The group must be divided into a number of component groups, each of which is sufficiently homogeneous in its general biology. In practice, these components are usually species, though in some cases species must be subdivided into subspecies or races to obtain sufficiently homogeneous groups.

(b) Distribution, regional and seasonal.

The geographical range of each species or race must be established to discover where it may be caught; it is also essential to know whether or not the supply of fish from a given locality can be maintained throughout the year, and, if not, for what period of the year it can be maintained.

(c) Size and chemical constitution.

A fish-marketing industry, particularly if it is engaged in the canning of whole fish, must be assured of a supply of fish of a given size range or ranges; while an industry engaged in the reduction of fish for oil and/or meal must be assured of a supply of fish of a certain range or ranges of oil content. It is, therefore, essential to study the ranges of both size and chemical condition of each species or race for the various localities concerned. In practice, the two qualities are often closely correlated.

(d) Fishing methods.

Trials must be undertaken to determine what type of boats and fishing gear can most efficiently and economically catch the various species in the various localities concerned.

(e) General natural history.

In order satisfactorily to link up the results of the previous lines of investigation, and especially for the purpose of explaining and predicting fluctuations therein, general biological studies on such factors as age, development, maturity, and feeding must be undertaken.

In the case of the clupeoid fishes, the first of these lines of investigation has already received considerable attention at the hands of various ichthyologists, and the species are fairly well known, though little investigation into possible racial differentiation has been made. Regarding the other lines very little has been accomplished, though we have a patchy knowledge of the regional distribution of some of the species. A programme of research into the economic biology of this group should, therefore, proceed immediately to these latter problems, whilst bearing in mind the necessity for racial investigations as the other studies proceed. Fully enumerated then, the objects of the clupeoid work must be researches into:-

(a) Distribution
(b) Size
(c) Chemistry
(d) Fishing methods
(e) Age
(f) Development
(g) Maturity
(h) Feeding
(i) Racial differentiation.

2. Limitations of the Study.

It was not to be expected, within so short a time of the commencement of the field programme of the Fisheries Division, that any finality would be achieved in respect of any of the previously mentioned objectives. In the first place, owing to pressure of work in a great many fields, there has not always been any opportunity to check the observations of one year with those of another and one cannot, therefore, unreservedly formulate generalisations out of these observations. Furthermore, as will appear below, considerable difficulty has been experienced in obtaining clupeoid material in sufficient quantities for full study at even any one place and season, rendering it always extremely difficult and in some cases impossible to make proper comparisons of phenomena as between different localities and seasons. In addition, owing to the shortness of the time he has been engaged on the study, the author has had no opportunity to study and work up the results of material and observations in respect of age, feeding, and racial differentiation, and has been unable to study maturity in very much detail. For these reasons only distribution, development, size, maturity, chemistry, and fishing methods are considered in any detail in this paper, and, in discussing these, all data obtained up to the end of February, 1940, is utilized.* The localities referred to are shown in Figs. 1, 2.

Apart from these limitations, which apply to the study of the clupeoid group as a whole, it should be noted that only a limited number of the Australian clupeoid species are actually considered here. In the first place the few strictly freshwater species do not of course come within the scope of the work of the Fisheries Division at present, and furthermore, as very little work is being done in waters north of the Tropic of Capricorn, only those species definitely known to occur to the south of it are open to consideration. Of these there are at least 13 (See Appendix A), only eight of which have so far been encountered in the course of the work of the Division. The principal part of our discussion is confined to seven of these, which, however, comprise the best known and commonest forms in the waters of south-eastern Australia. They are the pilchard (*Sardinops neopilchardus*),

* See Appendix D for a brief discussion of some later work.

southern herring (*Harengula castelnaui*), sprat (*Clupea bassensis*), sandy sprat (*Hyperlophus vittatus*), blue sprat (*Stolephorus robustus*), maray (*Etrumeus jacksoniensis*), and anchovy (*Engraulis australis*), the first four of which belong to the family Clupeidae, the fifth and sixth to the family Dussumieridae, and the last to the family Engraulidae. The eighth species encountered, the "scaly mackerel" (*Sardinella postera*), which belongs to the family Clupeidae, comes from south-western Australia and is very little known; it is therefore only briefly dealt with, in Appendix C.

3. Methods.

The main sources of information and material have been the research vessel, the mobile laboratory, Melbourne and Sydney Fish Markets, beach seining operations, fisheries inspectors, and private fishermen. In addition, some data have been obtained from aerial flights and commercial trawlers. The research vessel has, however, provided by far the bulk of the material and made most of the observations; her work has moreover been not only in relation to adult fishes, but to planktonic eggs and larvae.

As will be made clear below, the "Warreen's" lampara and purse-seine nets have so far not proved very useful for the capture of clupeoid fish. Most of the large samples obtained by her were caught with the aid of a submarine light and a "ring-net". This operation consisted of lowering over the ship's side, while she was at anchor or hove to at night, a bag of netting suspended from a large circular frame and closed at the bottom, and then lowering the submarine light into the open mouth of the net at a depth of about a fathom; by this means many clupeoids (especially pilchards) and other fishes were attracted into the net, and caught and brought aboard by suddenly raising the net out of the water. Drift-nets have also yielded some good samples. Another valuable source of information and (to a very limited extent) of material was the examination of the stomach contents of large pelagic fishes (tunas, salmon, and barracouta) caught on trolled lines; these proved fairly reliable as indications of what clupeoid species, if any, were in the vicinity, and often

served to identify with reasonable certainty the nature of shoals of small fish, which were observed but not directly sampled by the vessel. In one or two instances the stomach contents of demersal fishes (flathead, John Dory) also proved useful in this regard.

Valuable representative information as to the distribution of spawning clupeoid species was obtained from the plankton-netting routine of the "Warreen". Indeed these studies serve as a good example of the importance of this work in fisheries biology. This work was done regularly at sea in conjunction with the hydrological operations; on almost every cruise two observation stations were established and worked, one inside and one outside the edge of the continental shelf, for approximately every degree of latitude or longitude traversed along the coast. At these stations hydrological and plankton work were done together. The inside or shallow-water stations were generally worked where there was about 50 metres (28 fathoms) of water, while the outside or deep water ones were worked where there was at least 650 metres (360 fathoms).

Various forms of plankton-netting routine, comprising vertical, horizontal, and oblique hauls, have been tried from the "Warreen", and to assist in the understanding of some of the results given below some remarks about the procedure seem called for. Four different types of plankton nets were used, two being of silk with frames of 50 and 70 cm. diameter respectively, and two of stramin with frames of 100 and 200 cm. diameter respectively, these nets hereafter being referred to as the N50, N70, N100, and N200 respectively; all were made to the designs of the nets used by the "Discovery" expeditions (Kemp and Hardy, 1929, pp. 181-186) by the Marine Biological Association at Plymouth. The normal routine of work at a station was to perform the hydrological work first after heaving to; following this, vertical plankton hauls were taken with an N70, these hauls consisting at a shallow station of a single haul from a depth of 50 metres to the surface, and at a deep station of a series of hauls from 500 to 250 metres, 250 to 100 metres, 100 to 50 metres, and 50 metres to the surface, the first three of these of course necessitating the use of a closing mechanism; and subsequently the horizontal

and/or oblique hauls were performed, the vessel towing the nets slowly (at a speed of from 2 to 3 knots) away from the station and proceeding on her course at full speed at the close of this operation. The latter part of the routine was changed more than once. Originally only oblique hauls with the N70, N100, and sometimes the N200 were performed, and these mostly at deep-water stations, the nets being attached to the end of the wire and 200 metres paid away and hauled in at the rate of 10 metres a minute; this operation took about 20 minutes and a distance of slightly under a mile was covered. This method was found to yield catches insufficiently large for some purposes, so a routine consisting only of horizontal hauls was adopted, the N70 and N200 being towed together at the end of a paid-out length of 50 metres of wire for shallow and 200 metres for deep stations (i.e. at approximate depths of 25 and 100 metres respectively, the depth being calculated as roughly half the length of wire paid out), and the N50 and N100 being towed together at the surface; these tows generally lasted 30 minutes and a distance of about a mile and a quarter was covered. To get a better indication of the distribution of the plankton, however, it was later decided to modify the routine to include oblique as well as horizontal hauls, and a third technique, which is still in use, was adopted. In this routine a horizontal haul with the N70 and N200 together at the surface, and lasting 15 minutes, is first performed, followed by an oblique haul of the N70 and N100 together; at shallow stations 100 metres of wire are paid away for this operation, and at deep stations 400 metres, the hauls being thus calculated to traverse depths from 50 metres to the surface and from 200 metres to the surface respectively; the hauls take about 10 and 40 minutes respectively. No closing mechanism has been employed for any oblique or horizontal hauls.

The consideration in this paper of the planktonic eggs and larvae of the clupeoid fishes is based almost entirely on their occurrences in the N100 and N200 stramin nets, as these naturally caught these stages in larger numbers than the smaller silk nets. The catches from these nets, or, in some cases, convenient fractions by volume of the catches, were sorted and counted for clupeoid eggs and larvae. The results, for the eggs and larvae of the pilchard, and for the larvae

of the anchovy and maray, are presented in Table I. These results will be further discussed below, but one or two points regarding the table as a whole can be noted here. The positions of the stations are described with reference to the capes, bays, islands, etc. in the vicinity of which the stations were worked, and the symbols S. and D. in this column represent shallow and deep stations respectively; thus "Jervis Bay S" for example implies a position close to Jervis Bay within the edge of the continental shelf, while "Jervis Bay D" implies a position in approximately the same latitude, but over the edge of the continental shelf. Records of actual latitude and longitude are of course available for all stations, but it seems more convenient for the purposes of this study to locate them as is done here. No distinction as such is made in the Table between horizontal and oblique hauls, but this can easily be determined from the column giving the depths at which the nets were worked; thus "25" in this column indicates a horizontal haul at a depth of approximately 25 metres, while "100-0" indicates an oblique haul from a depth of approximately 100 metres to the surface.

A few points may be mentioned with regard to the methods employed for the handling of samples of adult clupeoid fish. Where possible such samples were kept preserved in a refrigerator until required; otherwise alcohol or formalin was employed as a preservative, though this rendered the fish much more difficult to handle on account of ensuing rigidity. Samples as large as possible were always taken, and every fish was measured for body length and, unless the sample was very large, for total length as well. "Body length", which was found in practice to be the more convenient measurement of the two, was defined following the technique adopted for the California sardine (Thompson, 1926, p.59) as the length from the tip of the snout to the end of the silvery area on the caudal peduncle as seen when the scales are scraped away, while "total length", following the same precedent, was defined as the length from the tip of the snout to the end of the caudal fin when the flukes are held parallel to the long axis of the body; all measurements were made on a measuring board of the type used in the California sardine and the Pacific

herring work (Thompson, 1916, pp. S 45-46, Fig. viii, and 1926, p.60) and to the nearest millimetre. If the sample exceeded a hundred individuals, a hundred were put aside for more detailed observation, this being of course concurrent with the measurement of those individuals; if it did not, the whole sample was treated in detail. These further observations included counts of rays for the dorsal, pectoral, and anal fins, and of vertebrae, in which latter count the hypural was always included; observations as to sex and maturity; the taking of scales and otoliths; and the determination, by displacement of water, of the mean volume of the stomach content of the sample, and of examination of the stomach contents to determine their nature. The condition of the gonads was referred to on the general basis of the maturity scale adopted by the International Council for the Exploration of the Sea (Wood, 1930, p.14), a summarized and slightly amended version of which is presented as follows:-

Stage I. Immature. Gonads very small, often hardly recognisable. Eggs invisible to naked eye, transparent under microscope.

Stage II. Gonads of length slightly more than half the length of the body cavity. Some eggs opaque, just visible to the naked eye.

Stage III. Gonads about half filling the body cavity. Eggs opaque.

Stage IV. Gonads about two-thirds filling the body cavity.

Stage V. Mature. Organs filling the body cavity but not discharging. Some large transparent eggs.

Stage VI. Spawning. Organs discharging or about to do so. Large transparent eggs.

Stage VII. Spent. Organs bloodshot, flaccid. Large residual eggs present.

The gonads of a few females in each sample were generally put aside with a view to future measurement of ova diameters.

Extraction of oil content of a sample, when made, was performed by mincing several whole fish, drying and grinding to a dry powder, and Soxhlet-extracting the oil with ether.

It may be noted that the terms Spring, Summer, Autumn, and Winter as used in this paper refer to the calendar months as follows:-

Spring	-	September, October, and November.
Summer	-	December, January, and February.
Autumn	-	March, April, and May.
Winter	-	June, July, and August.

II. THE PILCHARD.

Sardinops neopilchardus (Steindachner,1879).

(Plate 1, Figs. 1, 2.)

1. Synonymy, References, and Relationships.

Clupea neopilchardus Steindachner, 1879, p. 12.
Sardina neopilchardus (Steindachner), McCulloch, 1919, p. 172, Pl. xxvi., Fig. 1. (synonymy).
Sardinops neopilchardus (Steindachner), Whitley, 1937, p. 116. (further synonymy and references).

The last two of these references together give a complete bibliography of the species up to the date of the appearance of the third paper, to which the following references, arranged according to the names followed, should be added to bring it up to date.

Sardina neopilchardus (Steindachner), Graham, 1938, p. 402, and 1939b, p.362.
Sardinops neopilchardus (Steindachner), Dakin, 1937, pp.209-216, Pl. xi., Figs. 1, 2; Jowett and Davies, 1938, pp. 7, 9, 13, 20-21, 23-24, 32, 34-35.
'Pilchard', New Zealand, 1938, p. 12; Graham, 1939a, pp. 424-426, 433.

It should also be noted here that there are three published references to this species which appear to be erroneous. One must, therefore, add the following to the statement of the synonymy:

non *Clupanodon neopilchardus*, Waite, 1905, p. 58; Alexander, 1922, p. 479.
non *Sardinops neopilchardus*, Serventy, 1938, pp. 299-300.

These three references call for some comment. Upon examining recently the collection of clupeoid fishes in the Western Australia Museum, one of the author's colleagues, Dr. D. L. Serventy, was led to the conclusion that the specimens from Fremantle and the Swan River, that he had previously identified as *Sardinops neopilchardus* were not in fact this species, but were identical with another Western Australian form known to fishermen there as the "scaly mackerel".

Furthermore he discovered that all except one of the supposed specimens of *S. neopilchardus* in the Museum were also referable to this other form, including one (W.A. Mus. No. 82) whose label indicated that it had come from the Abrolhos Islands, and had been identified by Waite as *Clupanodon neopilchardus*. Since the Abrolhos is the locality given by Waite in the reference cited above, it is fairly certain that this specimen is the one he identifies there, and since Alexander, using Waite's name, bases his record for the same locality on material in the Western Australian Museum, it is obvious that these two references, as well as Serventy's, refer to the "scaly mackerel". This author has seen a specimen of this latter fish, obtained by Dr. Serventy from Albany, and finds it identical with a species described from Western Australia by Whitley under the name of *Amblygaster posterus* (Whitley, 1931b, p. 144). Some further notes on this species, under the name of *Sardinella postera*, will be found in Appendix C at the end of this paper.

All the published records of *Sardinops neopilchardus* from Western Australia are, therefore, invalid. That this species does exist there is , however, evidenced by the presence in the Western Australian Museum collection of a single specimen (W.A. Mus. No. 10711) presented by the Fisheries Department of that State; the label indicates that it has been identified by McCulloch as *S. neopilchardus*, and Dr. Serventy confirms this. We now return to a general consideration of the pilchard in Australia.

This species, which occurs in the waters of both Australia and New Zealand, is very closely related to the other known members of the genus *Sardinops*. These are *S. caerulea*, from the Pacific coast of North America; *S. sagax*, from Peru and Chile; *S. melanosticta*, from Japan; *S. ocellata*, from South Africa; and *S. dakini*, from Thursday Island (Hubbs, 1929, p.265; Whitley, 1937, p.114). The distinctions between these species, if any such actually exist, are very poorly understood; Hubbs (loc. cit.) states: "It is in fact not clear whether the species of these various regions are different from one another. Pending a much needed critical comparison of good material from all these localities, I merely list the species as usually recognised."

Regan (1916a, pp. 11-14) and Chabanaud (1926, p.158) recognise as separate species only *sagax* and *neopilchardus*, referring *caerulea*, *melanosticta*, and *ocellata* all to the former; Regan bases the distinction between the two species on the relatively longer head, shorter maxillary, and smaller number of gill-rakers in *neopilchardus*, while Chabanaud finds differences in the anatomy of the hyobranchial apparatus. Thompson (1926, p.9) lists *sagax*, *neopilchardus*, *melanosticta*, and *ocellata* as separate species, with *caerulea* as a possible fifth, but states that the inter-relationships of these species are insufficiently known and that it is doubtful whether *caerulea* and *sagax*, at least, can be properly separated. It is obvious, therefore, that the Australian pilchard can be regarded as very closely allied to the other species of its genus; this is a relationship of some potential importance, since the North American and Japanese species are extremely important commercially in those countries.

Furthermore, the genus *Sardinops* is closely related to the genus *Sardina*, which comprises *Sardina pilchardus pilchardus* and *S. pilchardus sardina*, the Atlantic and Mediterranean races of the European pilchard or sardine; indeed, although certain constant differences (in respect of color, scale characters, length of certain gill-rakers, and certain body and head proportions) between the European and the other species had previously been recognised by Regan (loc. cit.) and Thompson (loc. cit., pp. 9-11), the latter were only separated generically in fairly recent years (Hubbs, loc. cit., p. 262). Since *Sardina pilchardus* is also an extremely important commercial species, this relationship is again of considerable significance.

It is not without point, in a discussion of the relationships of the Australian pilchard, to add some remarks regarding the usage of the vernacular names "pilchard" and "sardine". The use of the term "pilchard" is confined in science and industry to species of the genera *Sardina* and *Sardinops*, and is so applied in the United Kingdom, British Columbia, and Australia to the species of those genera (i.e. *Sardina pilchardus*, *Sardinops caerulea*, and *S. neopilchardus* respectively) occurring in the waters of those countries; on the Pacific coast of the United States, however, *Sardinops caerulea*

is universally known and marketed under the name "sardine". This latter term has been rather more widely applied; in scientific usage it is generally applied to the small or immature individuals of the pilchard genera *Sardina* and *Sardinops*, but, as we have seen, on the west coast of the United States it is applied to these fish regardless of size. In the United Kingdom, by reason of a decision of the High Court in 1915, only fish of the European *Sardina pilchardus* (both subspecies) may be marketed as "sardines", the fish thus sold being probably mostly the small French - Spanish - and Portuguese-caught individuals, in distinction to the larger English-caught individuals of the same species, which are generally called, as noticed above, "pilchards": but in some other countries the use of the term "sardine" is extended to cover fish of quite different kinds. For example, in Canada it officially signifies "any small clupeoid fish", and so includes the young of the herring (*Clupea harengus*) and of other species of the Canadian Atlantic coast, as well as the Norwegian sprats or brisling (*Clupea sprattus*), which are marketed in Canada as "sardines" (Imperial Economic Committee, 1939, pp. 117-118). Thus, either term, or both, could perhaps be properly applied to the Australian species, but as the name "pilchard" is better known here and provides a stricter definition its use should be continued.

It should perhaps be noted that in Western Australia the name "pilchard" is often wrongly applied to the yellow-eyed mullet (*Agonostomus forsteri*).

2. Summary of Previous Knowledge.

Under this heading the results of previous observations upon the pilchard, as contained in the references already mentioned, are collected and summarized. This procedure will be followed elsewhere in this paper in respect of the other species discussed.

The observations of many workers upon this fish in New South Wales waters may be summarized by the statement, that, although pilchards may appear at all times of the year, their occurrence is most marked between May and September.

In this season they appear in vast surface shoals a few miles offshore, apparently generally moving northwards. Sometimes these shoals enter Port Jackson. The fish, however, may also frequent the bottom and middle waters, as they have been taken in trawls, both alone and in the stomachs of demersal fish, at depths of from 20 to 50 fathoms. This has occurred in February and March and possibly at other times. As to length, measurements of up to 10 inches in total length are given, fish between 9 and 10 inches being stated to be quite common. The eggs and larvae have been described and found to be most common between May and August; while very young fish, ranging in length from 38 to 56 mm., have been recorded from the Hawkesbury River estuary in October, 1936.

Pilchards have also been recorded along the Queensland coast as far north as Hervey Bay. Specimens taken at Moreton Island in September, 1908, were about 7 inches long. Others are stated to attain a length of at least 280 mm. (about 11 inches).

For Victoria the only records of pilchard occurrences are from Port Phillip. Here they were abundant between August and January in the years 1864 to 1871 inclusive. They also appeared there in 1909, when specimens measured ranged from 153 to 174 mm. in total length (about 6 to 6¾ inches).

Several authors testify to the occurrence of the pilchard in the waters of Tasmania. These fish were abundant in Storm Bay in August, 1922, and present in the neighbourhood of St. Helen's between August and November, 1924.

In South Australia pilchards have been recorded from St. Vincent's and Spencer Gulfs.

For Western Australia, as we have seen, no valid published records exist, but the species occurs there nevertheless.

The numerous records of pilchard occurrences in New Zealand waters suggest that these fish occur more or less constantly all the year round on the west coast of the South Island, and in Cook Strait, and perhaps all round the coast, but that their appearance at the surface is, for many localities at least, extremely sporadic. They are best known from the Marlborough Sounds district, where they are apparently present all the year

round, coming into the inlets in winter and retreating into more outside waters in the summer. Vast shoals have been reported as seen on the east coast of Otago and elsewhere in the South Island waters, principally in the summer months. Pilchards have been taken by trawlers in Hauraki Gulf in the month of September, and are also recorded from as far south as the Auckland Islands in June, 1912. They are said to reach a total length of 11 inches, though in the neighbourhood of Otago 5 and 3 inches are stated to be the maximum and the average size respectively. The spawning season is given as October, November, and December. Three larvae taken in plankton hauls near North Cape in September, 1911, have been referred to this species.

It will thus be seen that the known range of the pilchard extends practically throughout all Australian waters south of the Tropic, and throughout the waters of New Zealand.

3. Development Studies.

The eggs and larvae of the pilchard have been described by Dakin and Colefax (1934), and there is little to be added to this account. In specimens from the plankton catches of the "Warreen" however, the pigment appears at a much earlier stage than that stated by these authors. In fact, in specimens 3.5 mm. long, in which the yolk is still present, pigment spots are to be found along the ventral margin of the body, and pigment is also present in the eyes of a specimen 4.5 mm. in length. Specimens from Queensland and South Australia are all very similar to those described and figured at various stages by Dakin and Colefax for New South Wales fish.

In the largest pilchard larva described by Dakin and Colefax (28 mm. in total length) the dorsal fin is still well behind the ventrals, whereas in the adult fish it is opposite to them. In a series of postlarval pilchards taken at Jervis Bay in February, 1940, in which specimens ranging from 29 to 48 mm. in total length were found, it was noticed that the dorsal fin moved gradually forward in specimens of increasing length, and finally appeared in its adult position in specimens measuring 37 to 38 mm. in total length. It may also be noted that in this series the first vestiges of

surface body pigment, not described by Dakin and Colefax for their 28 mm. specimen, were apparent in 29 mm. specimens as a lateral series of pigment spots, and that the pigmentation was well marked, on the upper surface of the body as well as on the sides. by the time a total length of 37 to 38 mm. had been reached. A temporary lateral silvery stripe is sometimes developed in these postlarval stages.

The New Zealand larvae referred to this species by Regan (1916b, p.136, Pl. v., Figs. 3, 4) appear as figured to be fairly comparable with Australian material at those particular stages.

4. Distribution Studies.

To study the distribution of the pilchard, observations have been carried out on both the adult fish themselves and their pelagic eggs and larvae. These two lines of investigation are here discussed separately, and the conclusions resulting are then compared.

(a) Adults.

The evidence as to the distribution of adult fish was in the main obtained by the research vessel, though some data came to hand from other sources. Since it is inconvenient to describe the movements of the vessel in respect of the waters of each State separately, the area studied is considered as divided into three parts, viz., the waters of New South Wales and Queensland, of Victoria and Tasmania, and of South Australia. This arrangement furthermore seems a fairly natural one, since, as will be shown, the distribution in each of these regions appears to be governed by rather different circumstances.

(1) *New South Wales - Queensland.*

The first definite evidence obtained subsequent to the beginning of the investigations was for the month of:-

February, 1938, - A few fish were taken, together with sandy sprats, in Middle Harbour, Port Jackson, by officers of the New South Wales Fisheries Department.

The regular studies did not, however, begin until the "Warreen" commenced her series of exploratory cruises in these waters in -

August, 1938, - Coast traversed from Cape Howe to Sydney. No fish seen.

September, 1938, - Coast traversed from Sydney to the Capricorn Islands and return. A few shoals were seen off Coff's Harbour.

October, 1938, - Coast traversed from Sydney to Cape Howe and return. No fish seen.

November, 1938, - Coast traversed from Sydney to Cape Howe and thence northwards to Jervis Bay. No fish seen.

December, 1938, - Coast traversed from Jervis Bay to Twofold Bay, thence north to Port Stephens, thence south to Sydney. No fish seen.

January, 1939, - Coast traversed from Sydney to Cape Howe and return. No fish seen.

February, 1939, - Coast traversed from Sydney to Cape Howe. No fish seen. During the month the author, while aboard a trawler working off Jervis Bay, obtained three pilchards from the net after one haul in 40 fathoms.

March, 1939, - No observations, vessel absent from coast.

April, 1939, - Coast traversed from Cape Howe to Sydney. One pilchard was obtained from the stomach of a bonito (*Sarda australis*) off Brush Island. A few fish were also obtained during the month by beach seining in Port Hacking, once with anchovies, sandy sprats, and southern herring, and once with maray.

May, 1939, - Coast traversed from Sydney to the Capricorn Islands, thence south to Montague Island. Shoals of pilchards were very abundant between Seal Rocks and the Newcastle Bight, both by night and by day; a few specimens were also obtained from the stomachs of mackerel tunny (*Euthynnus alletteratus*) and bonito, off the Clarence River (with maray) and Solitary Islands, respectively. Twice during the month small lots, probably caught in Port Jackson, were offered for sale at the Sydney Fish Market (on one of these occasions maray were mixed with the pilchards): a trawler captain forwarded a specimen obtained from his net after a haul off Botany Bay in 45 fathoms.

June, 1939, - Coast traversed from Montague Island to Cape Howe, thence north to Camden Haven, thence south to Sydney. Shoals and small lots of pilchards were seen (the shoals by day only), or their presence was inferred, off Port Jackson, Bird Island, Red Head, Broughton Island, Cape Hawke, and Camden Haven: a specimen of maray was also taken with the pilchards at Camden Haven. Mackerel tunny were often in attendance, feeding on the pilchards.

July, 1939, - Coast traversed from Sydney to Mackay and return. Some pilchard shoals were seen off Coff's Harbour by day but not by night; a few specimens were also obtained from the stomachs of mackerel tunny off the Clarence River.

August, 1939, - Coast traversed from Sydney to Cape Byron, thence south to Cape Howe. Shoals of pilchards were seen, mostly by day, off Cape Hawke, Trial Bay, Coff's Harbour, Clarence River, Richmond River, and Cape Byron. Mackerel tunny were sometimes in attendance, feeding. (Plate 1, Fig. 2). A small lot of pilchards was offered for sale once during the month at the Sydney Fish Market; a Danish-seine fisherman forwarded a specimen found by him in the stomach of a John Dory (*Zeus faber*) from off Jervis Bay.

September, 1939, - Coast traversed from Cape Howe to Cape Byron, thence south to Sydney. A few shoals were seen by night near Cape Byron. Small lots of fish were offered for sale at the Sydney Fish Market on four occasions during the month.

October, 1939, - Coast traversed from Sydney to Cape Howe and return, thence to Jervis Bay. No fish seen. Two specimens were taken together with an anchovy, in a beach seine haul in the Wagonga River, at Narooma, during the month.

November, 1939, - Coast traversed from Jervis Bay to Cape Howe, thence north to Sydney, thence south again to Cape Howe. Three pilchards were obtained from the stomachs of bluefin tuna (*Thunnus maccoyii*) off Bateman's Bay. During the month a fair catch of pilchards, together with anchovies, was made with a beach seine in the Wagonga River, at Narooma.

December, 1939, - Coast traversed from Cape Howe to Sydney. No fish seen.

January, 1940, - Coast traversed from Sydney to Coff's Harbour, thence south to Twofold Bay. A few shoals of pilchards were seen at night in the neighbourhood of Port Stephens, and small catches made with drift nets.

February, 1940, - Coast traversed from Twofold Bay to Cape Howe, thence north to Sydney, and subsequently from Sydney to Cape Howe and return. A shoal, believed to be of pilchards, was observed off Wollongong, in the daytime. During this month and the one preceding the author and other officers of the Fisheries Division traversed the coast from Sydney to Maryborough and return in the mobile laboratory, making beach seine hauls in the principal inlets and estuaries. No adult pilchards were taken.

It might also be added that in the month of July, 1937, large shoals of small fish, believed to have been pilchards, were seen in the neighbourhoods of Port Stephens and Coff's Harbour by S. Fowler in the course of an aerial observation flight. This raises the question of the exact identity of fish shoals in the absence of any direct sampling, whether such shoals of small fish are seen from the air, from boats, or from the land. The question is an important one, as such instances are constantly being reported. Dakin (1937, p.211) draws attention to the difficulty of interpreting such observations, pointing out that these shoals are rarely sampled by fishermen or others, and that even when this is done the specimens are often incorrectly identified; he notes in the latter connection that he has received, under the name of "pilchard", samples of maray and sandy sprats.

It is the experience of the present author however, that while considerable doubt must rest on the identification of such unsampled occurrences of small fish from the inshore waters, such occurrences in the more offshore waters (two or three or more miles from the land) of New South Wales are mostly those of actual pilchard shoals. Congregations of small fish sampled in inshore waters, especially in estuaries and bays, have more often than not proved to be of species other than the pilchard. This is only to be expected in view of the fact that while (as these and other investigations show) the pilchard does not typically occur in these waters, many other species of small fish, including clupeoids (notably the blue and sandy sprats, both of which the author has seen identified by fishermen as pilchards), are not typically found outside them: but such congregations in offshore waters that have been sampled by the "Warreen" have generally proved to be pilchard shoals; the few exceptions were shoals of mackerel (*Pneumatophorus australasicus*), a species which, it may be noted, is often found closely associated with the pilchard in these waters.

On the basis of this experience it seems safe to say that the shoals of small fish that are observed, or whose presence is inferred from the diving of birds, more than two or three miles off these coasts can legitimately be assumed to be mostly composed of pilchards. Such a diagnosis would however be

strengthened if the shoals in question were observed to be, in general, elongate and attenuated rather than regularly circular or ellipsoidal in plan, or if (at night) they had the appearance of being slightly luminescent,* or if they were attended by a light pattering sound, like that of rain falling, since these are qualities which the work of the research vessel has shown to be particularly characteristic of pilchard shoals.

For these reasons the records of such shoals, even when not sampled, by the "Warreen" and by aeroplanes are here included as those of pilchards. It may be added that these records do not conflict with what is already known, or what is shown here by more definite evidence, regarding the distribution of this species.

Summarizing all the records, we notice first that very few of them refer to bays and estuaries, showing that the pilchard is not, in these waters, a typically inshore or shallow-water fish.† Most of the occurrences that are noted here are from waters between about two and eight miles off the land, and from these results and those of previous workers it seems clear that the pilchard is typically a fish of the offshore waters within the edge of the continental shelf, though at times entering the bays and harbours.† Summarizing next the occurrences of the fish for the four seasons, one finds:-

Summer - Occurrences from Jervis Bay to Port Stephens, but with few surface shoals (waters north of Coff's Harbour not traversed).

Autumn - Occurrences from Brush Island to Clarence River, with numerous shoals between Seal Rocks and Newcastle.

Winter - Occurrences from Jervis Bay to Cape Byron, with shoals between Port Jackson and Cape Byron.

Spring - Occurrences at Narooma, Bateman's Bay, and from Coff's Harbour to Cape Byron, shoaling in the latter region.

These results confirm the views of previous workers, that although the pilchard is present in these waters all the year round (at least those of New South Wales - it will be noticed that there are no records of pilchards from Queensland in these results), it is most conspicuous in the autumn, winter, and early spring, particularly the winter, when it appears off

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* Due to disturbance by the fish of small luminescent organisms.

† But see Appendix D.

the coast in surface shoals. The records of these occurrences indicate that such shoals are most common in waters between Sydney and Cape Byron, and especially in the winter months, though they tend to disappear, except in the most northern of those waters, by the spring.*

(ii) *Victoria - Tasmania.*

The first and only definite evidences obtained subsequent to the beginning of the investigations were for -

August, 1937, - A few pilchards were obtained for the Victorian Fisheries and Game Department from off Lakes Entrance: and for -

September, 1937, to January, 1938, - Pilchards, caught in Port Phillip, were frequently offered for sale in the Melbourne Fish Market. Since that time, according to agents there, no pilchards have appeared in the Melbourne Fish Market, and we have no further records of them in Victorian or Tasmanian waters. The results of the investigations of the research vessel are also negative, as will apear from the following summary:

May - June, 1938 - Cruised from Melbourne through Furneaux Islands and along eastern and southern coasts of Tasmania, and returned. No fish seen.

July - August, 1938, - Cruised from Melbourne through Furneaux Islands, thence north to Welshpool and along the Victorian coast to Cape Howe. No fish seen.

September, 1938, - No observations; vessel absent from these waters.

October, 1938, - Cruised from Cape Howe, via Babel Island to Hobart, and returned. No fish seen.

November, 1938, - Cruised from Cape Howe via Welshpool to Babel Island and thence returned directly to Cape Howe. No fish seen.

December, 1938, - No observations; vessel absent from these waters.

January, 1939, - Cruised from Cape Howe via Babel Island to Hobart, and returned via Babel Island and Welshpool. No fish seen.

February, 1939, - Cruised along entire Victorian coast. No fish seen.

March, 1939, - Cruised along Victorian Coast from South Australian border to Melbourne. No fish seen.

April, 1939, - Cruised from Melbourne via King Island and Banks Straits to Hobart, thence north via Babel Island to Cape Howe. No fish seen.

May, 1939, - No observations; vessel absent from these waters.

June, 1939, - Cruised from Cape Howe via Babel Island to Hobart and returned. No fish seen.

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* But see Appendix D.

July, 1939, - No observations; vessel absent from these waters.
August - September, 1939, - Cruised from Cape Howe to Furneaux Islands and returned. No fish seen.
October, 1939, - Cruised from Cape Howe via Babel Island to Hobart and returned. No fish seen.
November, 1939, - Cruised from Cape Howe via Babel Island to Hobart, and returned via Banks Straits, thence from Cape Howe to Melbourne. No fish seen.
December, 1939, - Cruised from Melbourne along Victorian coast to South Australian border and returned; thence via Banks Straits to Port Arthur and north via Babel Island to Cape Howe. No fish seen.
January, 1940, - No observations; vessel absent from these waters.
February, 1940,- Cruised from Cape Howe via Babel Island to Hobart and returned. No fish seen.

It should be added that in August, 1937, shoals of small fish were seen from the air between Lakes Entrance and Sydenham Inlet, and also in Port Phillip. Although as we have seen pilchards were taken from those waters at about that time, anchovies were also then taken in Port Phillip and were obtained off Lakes Entrance in the following August, and therefore the identification of the shoals is a matter of some doubt. In fact, as is indicated elsewhere, the anchovy appears to be generally more common than the pilchard in the waters (particularly offshore) of these States, especially Tasmania, hence the identification of shoals of small fish in these waters is a matter more liable to error than in New South Wales.

It also appears on excellent authority that pilchard shoals were present, for the first time in many years, in the eastern part of Port Phillip in May, 1934; and subsequently, from September, 1934, to May, 1935, in November and December, 1935, and in May, 1936. Whether they appeared towards the summer of 1936-1937 or not is unknown, but as we have seen already they were numerous from September, 1937, to January, 1938, but have not been reported since that time.

The only positive evidence as to the presence of adult pilchards in the waters under consideration is thus for Victoria, where we have a single record for the month of August for Lakes Entrance and several for the period September to May between 1934 and 1938 in Port Phillip. It is difficult to say whether the Lakes Entrance occurrence should be linked

with those in New South Wales or not, although it seems more likely that it should not, since pilchards do not seem to occur in the southern waters of that State at the end of the winter. The Port Phillip records seem definitely to show that here we are concerned with a body of fish behaving in a very different way to those in New South Wales; indeed the season at which they appear (and, as will be seen, at which they spawn) suggests that their affinities are with the pilchards of South Australia, and possibly the occurrence at Lakes Entrance could be linked to these also. At any rate, the Port Phillip records (including those of previous authors) show that in many, if not in all years, bodies of pilchards are present in the waters of southern Victoria in the warmer months (about August to May) of the year; actually it is more likely that they are always present in the outside waters at those times, but do not visit Port Phillip every year; we have already seen that the pilchard is in the main an offshore fish in the New South Wales region, and it could well be imagined that its appearances in a harbour with so narrow an entrance as Port Phillip would tend to be only sporadic.

Regarding Tasmania there is no positive evidence at all, although previous workers have definitely recorded pilchards from these waters. It cannot however be claimed that these waters have been exhaustively examined, since the only waters that have been regularly visited have been those of the east coast and of the Furneaux Islands; and it is quite possible that the fish may occur on the northern and western coasts. Indeed if there is, as the results suggest, a pilchard population centre in the waters of Victoria and South Australia, it is most likely that this population would range into the waters of northern and western, rather than eastern Tasmania.

(iii) *South Australia.*

The only evidence obtained from South Australian waters was procured by the research vessel on her only two cruises in that area. The first cruise was conducted in February and March, 1939, when practically the entire coastline east of Cape Catastrophe, except part of the southern coast of Kangaroo Island, was examined. Several pilchard shoals were seen about the western entrance to Investigator Strait, but in addition pilchards were found in the stomachs of bluefin

tuna throughout the entire area. On the second cruise, in December, 1939, the same area generally speaking was traversed save that the vessel did not proceed far into Spencer Gulf but worked as far west as Coffin Bay and also covered the south coast of Kangaroo Island. On this occasion no pilchard shoals were seen, but some were obtained from the stomachs of bluefin tuna along the east coast of St. Vincent's Gulf and in the neighbourhood of Backstairs Passage. These results added very considerably to our knowledge of the distribution of this fish in South Australia, as previously very little was known regarding pilchard distribution there.

Shoals of small fish, believed to be pilchards, were occasionally noticed in waters east and west of Eyre's Peninsula during an aerial survey in February and March, 1939.

(b) Eggs and Larvae.

Evidence as to the distribution of pilchard eggs and larvae was obtained entirely from the results of the plankton routine of the research vessel. Although of course this evidence can only be used as a criterion of the distribution of the spawning fish, it seems worthy of detailed consideration, as it is the only really representative evidence as to distribution that is available.

As has already been mentioned, the consideration of these pelagic stages is based here on their occurrences in the N100 and N200 nets. The data are presented in Table I, a general explanation of which has already been given. This table gives the numbers of pilchard eggs and larvae (expressed separately in the same column; e.g. 42 + 5 signifies 42 eggs and 5 larvae) counted in each catch, or in the stated fraction of each catch. Since the time taken for each haul and the depth at which it was made are also given, the catches of eggs, or larvae, or both together, can be compared throughout for either net for any one depth by calculating the counts of these stages which would be obtained in a certain fixed time; given that a certain number were found to occur in a haul, or in a fraction of a haul, of greater or less duration than that certain time.

This table presents the results of all hauls with the N100 and N200 nets to the end of February, 1940; since the regular plankton routine was put into operation at the

beginning of September, 1938, (some oblique hauls were made at a few stations before this date), we have an opportunity to compare, for some waters at least, the occurrences of pilchard eggs and larvae throughout all seasons of the year, both qualitatively and quantitatively. As before, the results for New South Wales - Queensland, Victoria - Tasmania, and South Australia will be considered separately.

(1) *New South Wales - Queensland.*

Figs. 3, 5, and 7 illustrate the distribution, irrespective of quantity, of pilchard eggs, larvae, and eggs and larvae together, for these waters during the four quarters of the year. The position as depicted for the summer quarter is based on combined data for two summers, those of 1938-39 and 1939-40; for the autumn and winter there are only data for 1939; and for the spring there are again two sets of data, one for 1938 and one for 1939, which have been combined. Each of the four sketch-maps in each figure represents the distribution of the particular stage or stages concerned, as revealed by an analysis of Table I, for the quarter specified; in each, the area examined, i.e. the area in which plankton stations were worked as described in the introduction, is shaded, and the positions at which the particular stages were found, regardless of number, net, kind of haul (horizontal or oblique), time of haul, or depth, are indicated. The results as shown for eggs and larvae show a reasonable degree of correspondence, and thus apparently justify their study in combination.

To differentiate, however, between regions in which these stages were more numerous than in others, i.e., to locate the centres of spawning for the various seasons, an attempt was made to map these occurrences quantitatively. To do this adequately, a certain net and a certain depth must be taken as a standard, a time of haul and fraction of haul counted must be fixed, and the counts of the various stages standardized, where necessary, to that time and fraction. Owing to the changes that were made in the plankton routine during the year under consideration, the selection of such a standard is rather difficult.

The horizontal haul with the N100 at the surface (0 metres) was the most frequent combination of net and depth, and this

was, therefore, taken as the standard, with all counts standardized to 30 minutes and to the entire catch, where this was necessary. For example a count occurring in the Table as 5 eggs and 10 larvae in 5/6 of the catch taken in 15 minutes, would be taken for this purpose as 12 eggs and 24 larvae. Since, however, in the last change of routine it was decided for other reasons to eliminate this combination and use the N200 at the surface in place of the N100, the results of this combination, related to the same standard time and to the whole catch, have also been utilized throughout for stations where there was no haul of the N100 at the surface. Several trial hauls were made with the N100 and N200 together at the surface, and their catches were counted and standardized as above for pelagic clupeoid individuals (eggs and larvae) to obtain a factor by which the N200 counts could be divided to render them comparable with those of the N100. In three of these trial hauls of the N100 and N200 together, clupeoid material occurred in both nets; the results standardized as above for each species are as follows:-

Station	Species	No. in N100	No. in N200	Ratio N100:N200
196/39	Maray (larvae)	5.0	37.5	0.13 : 1.00
198/39	Pilchard (eggs)	1022.0	1155.0	0.88 : 1.00
201/39	Pilchard (larvae)	115.0	1040.0	0.11 : 1.00
201/39	Anchovy (larvae)	2.5	20.0	0.12 : 1.00
201/39	Maray (larvae)	2.5	7.5	0.33 : 1.00

The mean ratio N100 : N200 is thus 0.31 : 1.00 (which is not significantly altered if the fish of all three species are considered together for station 201/39). For practical purposes, 1 : 3 may on this basis be accepted as a conversion factor and, therefore, all proportionated counts of eggs and/or larvae for the pilchard (and of larvae for the other two species, which are discussed later) in the N200 have been divided by 3.

The counts of pilchard eggs, larvae, and eggs and larvae together for these surface hauls have been mapped out for the four seasons, as before, in Figs. 4, 6, and 8. In cases where more than one surface haul was performed at the same position within the same quarter, the proportionate results

of all the hauls, including negative ones, were averaged. Where the corrected or proportionate value for a locality is less than 1 it is not mapped. It will be noticed that the method adopted for presenting the data greatly smoothes out the minor numerical differences; this is of course necessary, to eliminate as much as possible the errors due to the inadequacy of sampling and to the proportionating and correction of the counts. The results as thus shown, however, tally fairly well with one another and with the qualitative results, and there is considerable justification for drawing certain broad conclusions from the combination of both sets of results, as to the distribution of eggs and larvae, and thus of spawning pilchards.

It is obvious that, during the period under consideration, although some spawning pilchards were present in at least some of these waters (i.e., between Jervis Bay and Port Stephens) in all seasons, the greater volume of spawning took place in the winter and the least in the summer, with intermediate values in the autumn and spring. This is in accordance with the work of Dakin and Colefax (1933, pp. 212-213, and 1934, pp. 136-137, 139-140) and Dakin (1937, p.213) who found pilchard eggs to occur in the vicinity of Port Jackson (actually from Broken Bay to Port Hacking) from March to October, and larvae from April to November, but both most abundantly between May and August. It also appears that, although some spawning took place at all seasons in waters outside the edge of the continental shelf, it did so in much less volume than in more inside waters: the centre of spawning can, therefore, be assumed to have been generally inside the edge of the shelf, i.e. within about 15 miles of the coast.

Furthermore there is evidence of a certain shift of the spawning centre from season to season within this shallow-water belt. A glance at the maps will show that, while the spawning area for the year as a whole ranged from Twofold Bay to Sandy Cape (it may have ranged further north than this, though the pilchard has not been recorded from any lower latitude), there was, for three seasons at least, a well-marked snift towards the north both of the northern and southern (but particularly the former) limits of the range and of the spawning centres. Considering the qualitative

and quantitative results together, the seasonal distribution of spawning pilchards in these waters may be summed up as follows:-

Summer - Range from Twofold Bay to Port Stephens (the waters north of Coff's Harbour were not examined, but it seems unlikely that they would have yielded anything); most numerous at Jervis Bay.

Autumn - Range from Montague Island to Port Stephens; most numerous between Montague Island and Norah Head.

Winter - Range from Jervis Bay (and possibly somewhat further south, as the waters of Montague Island were not examined) to Cape Moreton; most numerous between Port Hacking and Cape Byron.

Spring - Range from Jervis Bay to Sandy Cape; most numerous between Coff's Harbour and Cape Moreton.

It thus appears that the total area over which spawning takes place in the summer extends from Twofold Bay to Port Stephens, but that very little spawning actually takes place at this time. For the autumn the area is about the same as for the summer, save that its southern limit (Montague Island) is rather more to the north, but the volume of spawning is significantly greater almost throughout. For the winter, it is doubtful whether or not the southern limit has shifted north to Jervis Bay or remained at Montague Island, but the northern limit is considerably further north, at Cape Moreton, and so is the spawning centre (Port Hacking to Cape Byron). For the spring, the southern limit (Jervis Bay) shows a definite shift northward at least from the autumn limit, while the northern limit (Sandy Cape) and centre (Coff's Harbour to Cape Moreton) are further north still.

Taken very generally, these conclusions as to the distribution of pilchard eggs and larvae, and hence of spawning pilchards, seem justifiable; the limits of occurrence here quoted represent of course only an approximation to the actual limits, and it is not only possible but probable that isolated cases of such occurrences might have occurred at any season well outside the main areas here suggested; but it seems clear that the main areas of occurrence for the four seasons were generally as stated. Furthermore it must be emphasised that these conclusions are based on data obtained over a

period of eighteen months only, and while they agree quite well with the rather limited similar results of other workers, at least two more years study of these pelagic stages will be necessary before definite conclusions can reasonably be drawn. Concurrently, hydrological observations should be continued and the results analysed in an attempt to find a correlation between these fish occurrences and some physical or chemical factor, the understanding of which would provide a basis for the prediction of any possible fluctuations. However, the tentative conclusions mentioned above provide us with at least a basis for further work on the pilchard, particularly in respect of the distribution of the adults and of fishing experiments.

It may be perhaps of some interest to note at this stage two occurrences of small postlarval pilchards in these waters. These were taken in January and February, 1940, at Nambucca Heads and Jervis Bay respectively; on each occasion postlarval anchovies were also present. These fish were of the same size as those found by Dakin (1937, p. 214) in the Hawkesbury River estuary in October, 1936. Since we do not know how old they were the significance of these finds remains doubtful.

(ii) *Victoria - Tasmania.*

Fig. 9 illustrates the occurrence of these planktonic pilchard stages in these waters during the four quarters of the year under consideration, in the same way as they were shown in the previous section. It will be noticed that there are two records only, one for the spring, off Wilson's Promontory, and one for the autumn, in Bass Strait about 40 miles north of the Tasmanian coast; furthermore these occurrences, as will be seen on reference to Table I, consisted respectively of a single egg and a single larva only.

Although it might be inferred that the pilchard is either not common in these waters or at any rate does not commonly spawn there, it is obvious that the waters have not been so exhaustively examined for such traces of pilchard as have those of New South Wales and southern Queensland. Actually, the only waters which have been regularly examined are those off the east coasts of Tasmania and the Furneaux Islands. It seems clear enough that these waters in the period studied

were at no season frequented by spawning pilchards in any concentration, but it is not impossible that they were present off the Victorian coast or off the western coast of Tasmania at some season during the year, while it is likely that more regular work in Bass Strait over several seasons would have revealed further and more definite traces of their presence. A further examination of these waters is required before any conclusions can be properly drawn, but it seems that the waters of the eastern coast of Tasmania are definitely unpromising, while those of Bass Strait indicate possibilities of the discovery of spawning pilchards there.

(iii) *South Australia.*

The only results available for these waters apply to the seas east of Cape Catastrophe for the months of February, March, and December, 1939, and are mapped in Fig. 10. It will be seen that the pilchard eggs and/or larvae were present in the offshore waters, the straits, and the mouths of the gulfs. The results are not expressed quantitatively, but reference to Table I will indicate that out of the five stations at which these stages were obtained one (St. 71/39, in the Investigator Straits proper) yielded catches larger than those generally obtained in New South Wales and Queensland, while two others (St. 98/39, in Lacepede Bay and St. 341/39, in St. Vincent's Gulf) yielded moderate hauls. This suggests that those months (i.e. those of the summer and early autumn) represent the main spawning season in those waters.

(c) General.

Under this heading the results and conclusions of the distribution studies on adult pilchards and on their eggs and larvae are compared, and the position summarized, for the three territories already considered.

(i) *New South Wales - Queensland.*

The results of the two studies are in fairly general agreement for New South Wales waters, though it may be noted at once that, while the presence of fair concentrations of pilchards in southern Queensland waters is indicated by the plankton studies for the winter and especially the spring, no adult fish have been obtained from those waters during

our investigations, either at those seasons or any others. This, of course, illustrates the value of the planktonic studies as an indicator of the whereabouts of the fish, and their superiority, within their own limits, in obtaining representative data as to distribution.

For New South Wales waters, we find a fairly close agreement for all seasons. The results for each season are compared and synthesised as follows:-

Summer:-

Adults:	Occurrences from Jervis Bay to Port Stephens; fish scarce, few surface shoals.
Eggs and Larvae:	Occurrences from Twofold Bay to Port Stephens; most numerous at Jervis Bay.
General:	Fish present from Twofold Bay to Port Stephens; little spawning, few shoals.

Autumn:-

Adults:	Occurrences from Brush Island to Clarence River; shoals near Port Stephens.
Eggs and Larvae:	Occurrences from Montague Island to Port Stephens; most numerous between Montague Island and Norah Head.
General:	Fish present from Montague Island to Clarence River; most numerous between Montague Island and Port Stephens, with shoals at least at the northern end of this area.

Winter:-

Adults:	Occurrences from Jervis Bay to Cape Byron; shoals frequent between Port Jackson and Cape Byron.
Eggs and Larvae:	Occurrences from Jervis Bay (and possibly further southwards) to Cape Moreton; most numerous between Port Hacking and Cape Byron.
General:	Fish present from Jervis Bay to Cape Moreton; most numerous between Port Hacking and Cape Byron, with shoals.

Spring:-

Adults:	Occurrences at Narooma, Bateman's Bay, and from Coff's Harbour to Cape Byron; fish shoaling in the latter region.
Eggs and Larvae:	Occurrences from Jervis Bay to Sandy Cape: most numerous between Coff's Harbour and Cape Moreton.

General: Occurrences from Narooma to Sandy Cape; most numerous between Coff's Harbour and Cape Moreton, with shoals at least at the southern end of this area.

It will be seen that for the winter, when the most thorough investigation in respect of the adult fish was done, the results tally particularly well.

The results of the distribution studies on the pilchard in these waters may now be summarized briefly as follows:- *

1. The range of the pilchard in the waters of New South Wales and Queensland is from Twofold Bay to Sandy Cape: it occurs mostly inside the edge of the continental shelf.

2. It occurs in at least some of these waters, especially those of the central sector of the New South Wales coast, all the year round, but does not spawn much, has possibly rather a restricted range, and is not conspicuous at the surface in the summer months.

3. In the late autumn, winter, and early spring, especially the winter, there is a major spawning season during which the fish often appear at the surface in shoals, mostly by daylight.

4. The main concentrations of fish, particularly of spawning fish, tend to appear in different sectors of the coastal waters at different periods to the spawning season: in the south and central sectors of the New South Wales coast in autumn: in the central and northern sectors in winter; and in the northern sector, and in southern Queensland waters in spring.

(ii) *Victoria - Tasmania.*

The results of the two studies are too incomplete to show any real agreement, and for the same reason it is impossible to make very much in the way of a general statement about the distribution in these waters. From all the evidence it seems likely that pilchards occur characteristically off the southern and possibly the eastern coasts of Victoria, and perhaps the northern coast of Tasmania and Bass Strait, in the spring, summer and autumn at least, perhaps all the year round. From time to time pilchards enter Port Phillip and perhaps other bays. Some spawning apparently takes

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* See also Appendix D.

place in Bass Strait in the spring and autumn, and possibly at other times. The waters of the Furneaux Islands and the eastern coast of Tasmania do not appear to be much frequented by pilchards at any season of the year.

(iii) *South Australia.*

The results of the two studies are not very far-reaching, but they agree reasonably well. It can be said that spawning pilchards are conspicuous, largely in surface shoals, in the shallow waters of eastern South Australia in the summer and early autumn at least.

5. Length Studies.

The pilchards measured, from all Australian localities (excluding obvious post-larvals), ranged in body length from 54 to 185 mm., i.e. from 65 mm. (2.6 inches) to 213 mm. (8.4 inches) in total length.

Length data are available for pilchards from the waters of New South Wales, Victoria, and South Australia only, These are now discussed separately. Observations on a sample of pilchards from New Zealand are also appended.

(a) New South Wales.

The fish ranged in body length from 54 to 185 mm.; as is noted above, the largest of these is only equivalent to 8.4 inches in total length, and, since over 4500 specimens have been measured, statements by previous authors to the effect that this species commonly obtains a length of from 9 to 10 inches would seem to have been exaggerated or based on inadequate sampling.

The exact number of specimens measured was 4769, and the mean body length of these is 129.48 mm., i.e. a total length of almost 151 mm., or just under 6 inches. This figure is a little biased since, of the total number of pilchards measured, slightly more than half, viz., 2387, comprised a single sample, with a mean body length of 123.06 mm., i.e. 144 mm., or 5.7 inches, in total length. Nevertheless the bias is not very great since the mean body length of the remaining 2382, comprising 24 samples, is only 135.92 mm., i.e. 159 mm., or 6.3 inches, in total length. Even this figure is much lower

than the previously published data would have led one to expect, but the extent of the sampling commands respect for the results. It may be noted that, except for 4 specimens, all these pilchards were taken between April, 1939, and January, 1940.

A body length frequency polygon constructed for these New South Wales pilchards reveals at least three major modes, at 95, 120, and 163 mm., respectively (i.e. 112, 140, and 189 mm., or about 4.5, 5.6, and 7.5 inches, in total length), representing three size-groups, which may or may not be age-classes. This graph is not reproduced here, as apart from this information the only thing it shows is the relative importance of the size-groups one to another which, owing to the irregularity of the sampling and the very great variation in the sizes of the samples, cannot be reliably regarded as representing the condition of the whole pilchard population.

(b) Victoria.

The fish obtained from Victorian waters, 241 in number (235 being from Port Phillip), ranged in body length from 113 to 161 mm., i.e. from 132 mm. (5.25 inches) to 187 mm. (7.4 inches) in total length. The mean body length is 147.08 mm., i.e. 171 mm., or 6.8 inches, in total length. All the specimens were taken between August, 1937, and January, 1938. The body length frequency polygon indicates only one size-group of any importance, with a mode at 150 mm., i.e. 174 mm., or 6.9 inches, in total length.

(c) South Australia.

Only 27 specimens have been obtained for measurement from South Australian waters and these, taken from the stomachs of bluefin tuna, were in indifferent condition. The measurements may not, therefore, be quite accurate. However the range in body length of those measured is from about 71 to 174 mm., i.e. from about 85 to 199 mm., or 3.4 to 7.9 inches, in total length. The mean body length is 87.33 mm., i.e. 103 mm., or 4.1 inches, in total length, but the material is far too inadequate to place any reliance upon this figure.

(d) New Zealand.

Through the courtesy of the staff of the Fisheries Laboratory of the New Zealand Marine Department, a sample of

150 pilchards taken in Queen Charlotte Sound in March, 1939. was made available for measurement and other studies. The fish in this sample ranged in body length from 141 to 200 mm., i.e. from 170 to 236 mm., or about 6.7 to 9.3 inches, in total length. The mean body length is 165.83 mm., i.e. 193 mm., or 7.6 inches, in total length. The body length frequency polygon indicates one principal size-group, with a mode at 169 mm., i.e. 196 mm., or about 7.75 inches, in total length. It will thus be seen that these pilchards tended to be rather larger than any from Australian localities.

It may be of interest to note here that the Californian pilchard or sardine (*Sardinops caerulea*) attains a body length of about 280 mm., or a total length of about 13 inches, and that the modes of size, in the commercial catch at least, range generally between 160 and 260 mm. of body length, or between about 7 and 12 inches of total length (Clark, F.N., 1931). The Atlantic *Sardina pilchardus pilchardus* and the South American *Sardinops sagax* attain lengths of a rather similar order, the former even attaining a total length of 350 mm., while the Japanese *Sardinops melanosticta* and the South African *S. ocellata* appear more similar to the Australian species in this respect, and the Mediterranean *Sardina pilchardus sardina* is somewhat smaller still (Regan, 1916a, pp. 12-14).

6. Maturity Studies.

Observations as to the maturity stages of the gonads of pilchards were made upon material from New South Wales, Victoria and South Australia. The results of these are discussed separately.

(a) New South Wales.

The great majority of specimens measuring over 130 mm., in body length, and some below that size, that were taken from May to September, 1939, had gonads exhibiting maturity stages from IV to VII, mostly the last, indicating that they had spawned, or would mostly do so, within the limits of that season. This condition was found in every sample save those composed only of fish under 130 mm. Specimens taken earlier,

off Jervis Bay in February and in Port Hacking in April, had gonads at stage III, and these also could have been expected to have attained maturity during that season. Specimens taken later, in November (Narooma) and January (Port Stephens), exhibited maturity stages I to III. The main spawning season is, therefore, certainly from May to September, which in agreement with the results of the work on eggs and larvae.

For the pilchard as well as for the southern herring, sandy sprat, blue sprat, and anchovy, it is possible on the data already to hand to calculate roughly the range of length at first maturity. Owing to the inadequacy of the data, however, it seems best to defer publication of these conclusions for the present.

(b) Victoria.

The specimens obtained from Victorian waters, which were taken between August, 1937, and January, 1938, were not very carefully examined for maturity stages. It can, however, be said as regards the fish from Port Phillip that these exhibited maturity stages from I to VII between September, 1937,and January, 1938, the fish at stages V to VII, i.e., spawned, spawning, or about to spawn, being taken mostly in January, when even then they only comprised about half of the number sampled. These facts suggest that there is a spawning season in these waters during the summer months, perhaps with a peak about February. This indicates close affinity with the South Australian pilchard, which, as we have seen from the studies on eggs and larvae, spawns also in the summer and autumn, rather than with the New South Wales fish which is a winter spawner.

(c) South Australia.

Of the few fish procured from South Australian waters in February and March, 1939, and in December, 1940, all except one were at stage I; but as the largest of these attained a body length of only 95 mm. one would not expect them to have matured at all in that season. The other specimen, taken in March, 1939, and measuring about 174 mm. in body length, was at stage IV, and it might be assumed that it would have spawned shortly. Thus what little evidence is available confirms the conclusions previously arrived at, from the studies of pilchard eggs and larvae, as to the summer to autumn spawning season for the pilchard in South Australia.

7. Chemistry.

The data so far obtained relating to the water and oil content of the pilchard are presented in Table II. It will be noticed that the first results obtained, i.e. those of Jowett and Davies for Port Phillip fish taken in the months of September, 1937, and January 1938, revealed a very low oil content (1.08 to 1.25 per cent of the whole fish). As it was shown by Dill (1921) that the oil content of the allied Californian pilchard or sardine increases with size, it was hoped that analysis of fish of larger size would show a higher oil content. These hopes were, however, dashed when an analysis of a sample of much larger fish, taken in New South Wales waters in August, 1939, revealed an oil content much lower even than in the first samples (0.32 per cent of the whole fish). It was obvious, therefore, that some other factor was at work, and, since the Victorian fish were mostly approaching the spawning period and the New South Wales ones were mostly past it, i.e. spent, and since it has been noticed by other authors for clupeoid species that the oil content becomes very low around the spawning period, this factor was assumed to be sexual maturity. Johnstone (1915, pp. 216-223), Bjerkan (1917, p.23 *et.seq.*), and Lovern and Wood (1937) are amongst those who have noticed this relation in the North Atlantic herring, and Hart *et al.* (1938) have demonstrated it in the North Pacific herring. Moreover, F. N. Clark (1928, pp. 24-27) finds for the Californian pilchard that fish larger than 200 mm. decrease in fat content from January to May, while fish between 150 and 200 mm. increase in fat over the same period. Since subsequent work has shown that for this fish most of those over 200 mm. become mature and large percentages of those under that size do not (Clark, F. N. 1934, pp. 22-23), and that the peak of the spawning season is in April and May (Clark, F.N., 1934, pp. 25-34), it seems that, as Clark originally suggested, these observations too may be explained on the basis of a reduction in oil content towards the spawning season.

On the basis of all this it was concluded that if fish of a similar size to those already mentioned could be obtained outside the spawning season they would contain appreciably

more oil. This was strikingly proved shortly afterwards by the analysis of a sample of pilchards with immature gonads taken in New South Wales waters in January, 1940, since, although their average size was less than that of the fish taken there in August, the oil content was very much higher (14.02 per cent. of the whole fish). It is clear, therefore, that fish of high oil content must be sought outside the spawning season, i.e. in the summer in New South Wales and probably in the winter in Victoria and South Australia.

Dr. F. B. Shorland, of the New Zealand Department of Agriculture, has kindly given permission to the author to publish some results of analyses for oil content on the New Zealand pilchard which is, as we have seen, the same species as the local form. The figures given for body length and maturity ranges of these samples have been deduced from information supplied by Mr. A. M. Rapson of the New Zealand Fisheries Laboratory. These results indicate moderately high oil contents (5.69 to 8.30 per cent. of the whole fish) which are probably again to be correlated with the immature condition of the fish at that season, though evidently either the maturity stages are not after all strictly comparable with those of New South Wales taken in January or there is some other factor operating, because we note that the oil content for fish from New Zealand larger than these is nevertheless a good deal less than that for the New South Wales specimens. Dr. Shorland's figures also confirm what was assumed previously, that increased size is a factor to be correlated with increased oil content.

8. Fishing Methods.

The fishery for the pilchard of the Pacific coast of North America is carried on in the main by means of two types of large surface seine-nets, the lampara and the purse-seine.* A net of each type was provided for the "Warreen" in order to determine whether or not these types of gear were suitable for pilchards in Australian waters.

The purse-seine net aboard the "Warreen" is mainly of a 1-3/8 inch mesh, which is smaller than that generally used in

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* Also a third type, called the "ring net", which is rather a combination of these two (see Fry, D.H. (1931)-Div.Fish.Game, Calif. Fish. Bull. 27).

such nets in the California fishery (1¾ inch, see Phillips, 1930, p.7), and the bag of the lampara is of ½ inch mesh, which is again rather smaller than that used in California (¾ to 1 inch, see Scofield, 1929, p.30).

In California there is apparently no difference, within the limits of the sizes of fish generally sought for the commercial catch, in the sizes taken by the finer-meshed lampara and the coarser-meshed purse-seine nets (Phillips, 1937, p.29, and Clark, G. H., 1935, p. 58). As we have seen, the limits of size for this catch are in the region of 160 to 260 mm. of body length, and since the uppermost limit of size for the Australian species, at least as far as these investigations have shown, is 185 mm. of body length, it was considered unlikely, after the measurement of the first few samples, that the purse-seine with so large a mesh would be able to capture these fish. Accordingly the purse-seine was not used.* The lampara was, however, of sufficiently small a mesh to retain these fish, and four trials (for pilchards; see section on anchovy for other details of lampara fishing) were accordingly made, two in South Australian waters in February and March, 1939, and two in New South Wales waters in May and August, 1939. All were made by daylight. All four trials were unsuccessful as, although on each occasion the net was satisfactorily shot around a shoal, the fish always either sounded or escaped through the wings of the net.

It seems likely that these failures are to be attributed to the fact, noticed on numerous occasions, that the pilchards are extremely shy, and tend to scatter or sound when disturbed. Possibly this could be overcome by fishing at night-time but, as has already been shown, such shoals have seldom been observed at night, and weather conditions have precluded night fishing trials.* However, the fact that these difficulties can, at times at any rate, be overcome is attested to by information made available by courtesy of Kangaroo Investigations Pty. Limited, of Port Lincoln, to the effect that their vessel has made four catches, of about a ton of pilchards each, with a lampara net in South Australian waters during the late summer and early autumn of this year (1940); one of these hauls was made in daylight, two at dusk, and one at night. The position of the efficiency of the lampara net, therefore,

* See Appendix D.

still remains obscure, though the conclusion seems inevitable that the immediate outlook for a fishery conducted on American lines is less encouraging than had been anticipated. Even were the other difficulties consistently overcome it seems likely that considerations of bad weather, rendering the use of such surface seines difficult or impossible, and of sharks, which would be likely to inflict considerable damage on the nets when full of fish, would tend to considerably reduce the utility of this type of gear. These considerations appear to apply to Australian waters, especially those of New South Wales, to a much greater extent than to those of California.*

In the Japanese pilchard fishery, in addition to purse-seines and similar nets, drift-nets are used to a considerable extent (Schepers, 1935, pp. 97-98), and this type of net is also used largely in the European pilchard or sardine fisheries (Cunningham, 1896, p. 169). It was, therefore, deemed likely that such nets would be useful for catching pilchards in Australian waters, and accordingly a few trials have recently been made by the research vessel with them, the mesh sizes being 1¼ and 1½ inch. To date only small lots have been taken,† although, since the trials have been made at the surface off the New South Wales coast during the summer (January,1940), when as we have seen, the fish are not very common at the surface in that locality, these trials do not represent a complete testing of the gear; possibly drift nets sunk deeper down in the summer, and used at the surface in the winter, would make better catches. Drift nets can be used at times when the weather precludes the working of surface seines, and they would also, if adjusted to appropriate depths, be likely to catch fish over a much more extended season than would be consistently possible at the surface; though they would not, of course, take fish in such quantities as the lampara and purse-seine types, and would probably be no less vulnerable to sharks.

In so far as pilchards tend to enter bays and harbours, beach-seines and traps might be of use in catching them. Indeed the few that are caught at present are mostly taken by the former means, but, as we have shown, they are more characteristic of the offshore waters, and their occurrence inshore seems to be rather sporadic.* In the Marlborough Sounds district of New Zealand these fish are caught in beach-seines, and small nets of the purse-seine type.

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* See Appendix D for further discussion.

† Mostly in the 1¼ inch mesh.

III. THE SOUTHERN HERRING.

Harengula castelnaui (Ogilby, 1897).

1. Synonymy, References, and Relationships.

As no full list of references has been given by any previous author, these are presented, according to the synonyms followed, as under:-

Clupea hypselosoma, Castelnau (non Bleeker), 1878, p. 355; Macleay, 1879, p. 375; Klunzinger, 1879, p. 416; Macleay, 1881, p. 259; Tenison-Woods, 1882, pp. 86-87; Ogilby, 1886, p. 56; Saville-Kent, 1893, pp. 302, 370.

Clupea sundaica, Macleay (non Bleeker), 1879, p. 373, and 1881, p. 259; Tenison-Woods, 1882, p. 86; Macleay, 1883, p. 209, Ogilby, 1886, p. 56, and 1893, p. 182, Pl. xlvi; Saville-Kent, 1893, pp. 301, 311, 370.

Kowala castelnaui Ogilby, 1897, p. 66; Tosh, 1903, p. 19, Pl. iii., Fig. 3.

Sardinella castelnaui (Ogilby), Waite, 1904, p. 13; Stead, 1906, p. 29, Fig. 11, and 1908, p. 26, Pl. v; Roughley, 1916, p. 15.

Harengula castelnaui (Ogilby), Cockerell, 1915, p. 36; Regan, 1917b, pp. 386, 391; McCulloch, 1921, p. 17, Pl. v., Fig. 55a; McCulloch and Whitley, 1925, p. 132; McCulloch, 1929, p. 39; Stead, 1930, pp. 68, 71, 74, Fig.; Dakin, 1937, pp. 211-212.

The genus *Harengula* contains a large number of species, mostly tropical or sub-tropical, none of which are at present of any outstanding economic value. A discussion of the inter-relationships of the species, and of the genus with other genera, is given by Regan (loc. cit., pp. 377-395). The use of the term "herring" for this and other species of the genus in Australia is based on their general appearance only, and should not be taken to imply any particularly close relationship with the well-known and extremely valuable herrings of European and North American waters, which belong to a different genus (*Clupea*).

2. Summary of Previous Knowledge.

The southern herring (so called to distinguish it from other species in tropical Australian waters) is best-known from the waters of New South Wales, though even here the facts as stated by previous authors are scanty and rather contradictory. The only localities specifically quoted for its occurrence are Port Jackson and the Hawkesbury River estuary. Some authors regard it as predominantly a sea-going fish, only rarely entering the bays and estuaries in stray lots, and being noticeable in the winter months when it congregates in great shoals moving, generally northwards, a few miles offshore; while another view is that its usual habitat is the waters of the estuaries, though at times it shoals off the coast.

For Queensland, this species has been recorded as far north as the Burdekin River, though it is generally regarded as being, in this State, a fish of the southern waters. The herrings have been observed in fair quantity in the Nerang River in the early winter, moving up the river in shoals in March; they have also been recorded from Moreton Bay.

This fish is not known from any other waters but these. Regarding its size, it is stated that it reaches a length of about 9 inches but that the average is less, about 6 inches.

3. Distribution Studies.

All the occurrences of herrings that have been noticed during the investigations of the Fisheries Division relate to adult fishes, and have been from the waters of New South Wales and southern Queensland. They may be summarized as follows:-

April, 1939: A specimen was taken in a beach seine haul in Port Hacking, together with pilchards, anchovies, and sandy sprats; while later in the month two specimens were obtained from a shoal just outside Port Hacking.

November, 1939: Three specimens were taken from a shoal just outside Port Hacking.

January-February, 1940: During these months the author and other officers of the Fisheries Division traversed the coast from Sydney to Maryborough and return in the mobile

laboratory, making beach seine hauls in the principal inlets and estuaries. Herrings were taken in all these waters, viz: Lake Macquarie, Port Stephens (Tea Gardens; North Arm entrance), Lake Wallis (about three miles from the entrance), Manning River (Taree), Port Macquarie, Nambucca River (about four miles from entrance), Clarence River entrance (Yamba; Iluka), Richmond River (Ballina), Tweed River (about five miles from entrance), Nerang River (Southport), Maroochy River (Maroochydore) and Noosa River (Tewantin). At Lake Wallis and Manning River a few sandy sprats were taken together with the herrings.

These observations, together with the facts that no occurrences of herrings have been noted by the research vessel and that no larvae referable to this species have been found in her plankton collections, suggest that this species is mostly confined to the waters of the estuaries and inlets, though sometimes occurring in the open waters just outside them. It will be seen that most of the records of the species refer to the late spring or summer months, but as it was found in Port Hacking in April as well it may also occur in other localities at that time, or at other times. According to many of the fishermen and Fisheries Inspectors, it is to be found in most of the localities mentioned above at all times of the year.

The regularity with which this species was taken in all waters fished, as a result of what were largely speculative hauls, was a striking feature of the traverse of the coast referred to above. Generally mullet and *Ambassis* spp. were taken with it. Most of the hauls yielded only small to moderate catches of herrings, but in one case, at Ballina, a good haul was obtained.

4. Length Studies.

The fish measured, from all localities, were 1627 in number: they ranged in body length from 43 to 153 mm., i.e. from 55 to 200 mm., or 2.2 to 7.9 inches, in total length. The mean body length was 91.32 mm., i.e. about 122 mm. or 4.8 inches in total length. A body length frequency polygon of all the specimens indicates only one size-group of any

importance, with a mode at 87 mm., i.e. 115 mm., or 4.6 inches, in total length. It will be borne in mind that, except for three specimens, all these fish were taken between the months of November, 1939, and February, 1940.

5. Maturity Studies.

The specimens taken at Port Hacking in April, 1939, had gonads at stage I. Those taken between November, 1939, and February, 1940, exhibited all maturity stages between I and VII. Those of this latter group at stage I were, however, mostly the smallest specimens, which it might be supposed would not reach first maturity at anything approximating those sizes; while of the remainder it may be said that the majority of the herrings were approaching maturity (maturity stages III to V), while quite a number had spawned (stage VII). It seems, therefore, that the summer and probably the early autumn represent a spawning season for the southern herring, and that spawning takes place in the estuaries and inlets.

6. Fishing Methods.

The herring can be caught in beach seines or gill nets. Traps might also be of some use. The experience of the author in seine-hauling for this fish is that, while clean, sandy grounds yield good catches, weedy, muddy localities (which of course are those which one is mostly obliged to work in rivers and open lakes) are not to be despised. The fish do not often come into the shallows, and localities for hauls should be chosen so that the bunt of the net is shot in at least 9 to 10 feet of water.

IV. THE SPRAT.

Clupea bassensis McCulloch, 1911.

1. Synonymy, References, and Relationships.

The following is a full list of references, arranged according to synonyms:

Clupea sprattus, Gunther (non Linné), 1871, p. 672; Macleay, 1881, p. 259; Johnston, 1883, pp. 93, 133, and 1891, p. 37; Saville - Kent, 1897, pp. 154, 175.

Clupea bassensis McCulloch, 1911, p. 16, Pl. iv., Fig. 2; Regan, 1916a, p. 5; Waite, 1921, p. 37, Fig. 52, and 1923, p. 58, Fig. ; Lord, 1923, p. 63; Lord and Scott, 1924, p. 31; Lord, 1927, p. 23; Whitley, 1929, p. 45: McCulloch, 1929, p. 38; Norman, 1936, p. 492.

Maugeclupea bassensis (McCulloch), Whitley, 1932b, p. 332.

Regan (1916a, p.3) presents a synopsis of the species of *Clupea*, subsequently added to by himself (Regan, 1917a) and by Norman (1936, p. 492). In this we find three groups of species distinguished, those with 9 (rarely 8 or 10), those with 8, and those with 7 rays in the ventral fins; the first comprises the highly important herrings of the North Atlantic and North Pacific (*C. harengus* and *C. pallasii*), the second has *C. bassensis* and three other little-known species (including one, *C. antipodum*, from New Zealand), and the third has the valuable sprat or brisling of the North Sea region (*C. sprattus*) together with two other little-known forms. It may be noted also that the species of the first group are described as having vomerine teeth, those of the third as having none, and the species of the second as being mixed in this respect; also that the observed range of the gillraker count for the second group is intermediate between that of the first and third.

However, Whitley (1932b, p.332) makes *C. bassensis* the type of a new genus *Maugeclupea*, which he defines as having, *inter alia*, ventral fins with eight rays: in a subsequent publication (1937, p.118) he also includes, as one might expect, *C. antipodum*. His reason for creating this new genus seems merely to be that McCulloch (1911, p.16) employed a subgeneric name (*Pomolobus*) for *C. bassensis*, and that this

name actually applies to a genus very distinct from any of the forms under discussion. This would perhaps be fair enough had McCulloch put forward any reasons as to why a subgeneric designation was required at all, but as he did not there seems little necessity for putting forward a new subgeneric, let alone generic, name after having, legitimately, dropped *Pomolobus*. Furthermore, Whitley's name is any case invalid as a *nomen nudum* since it does not comply with Section (c) of Article 25 of the International Rules of Zoological Nomenclature, as amended in 1927, which required generic or specific names published since 1930 to be accompanied by a summary of characters, or references to such a summary, which differentiate the genus or species from other genera or species. Quite apart from all this, however, it seems to this author a most incorrect proceeding to set up a new genus for a group, which as we have seen in this case, is intermediate, in respect of important characters, between two other groups of the same original series of species, while allowing these two other "extreme" groups to remain, as Whitley apparently does, under the old name. Accordingly, until such time as some more satisfactory disposition of the species is suggested, the species under consideration should be retained in the genus *Clupea*.

This is a relationship of considerable significance in view of the fact, already mentioned, that this genus also includes the valuable North Atlantic and North Pacific herrings, as well as the North Sea sprat or brisling. It appears from the synopses given by Regan and Norman that *C. bassensis* is closer to the sprat (*C. sprattus*) than to the herrings, since neither of these forms has vomerine teeth and as the gillraker counts are very similar in both; and indeed it should be noted that the Australian form was formerly referred to *C. sprattus*. It seems, therefore, correct to continue the use of the term "sprat" for it.

2. Summary of Previous Knowledge.

The sprat is best known from the waters of Tasmania, where it is stated to appear in large shoals off the coast, especially between August and November, sometimes entering

the estuaries of such rivers as the Tamar and Derwent. Small numbers are said to ascend the Tamar as far as Launceston each March. In 1844 they entered the Derwent in enormous numbers. In 1867 an enormous shoal drove ashore at Bruni Island. They have also been recorded from the east coast of Flinders Island. Lengths recorded range from about 4 to 6¼ inches.

This species is also stated to occur in South Australia, but no details are available.

3. Further Studies.

There is little that can as yet be added to our knowledge of the sprat, as it has only been encountered in the field on three occasions during these investigations. In october, 1937, several specimens were obtained from the stomachs of barracouta (*Thyrsites atun*) taken in Storm Bay, Tasmania; these ranged in body length from 104 to 120 mm. and in total length from 121 to 140 mm., or 4¾ to 5½ inches, and exhibited maturity stages from II to V. In December of the same year a few more specimens were obtained in the same way from the same locality; these were about the same size as the previous lot, and exhibited maturity stages from V to VII. In March, 1938, a sample was received from Sandy Bay, near Hobart, of fish of this species ranging in body length from 35 to 66 mm., and in total length from 42 to 78 mm., and with gonads at stage I: these fish were stated to have been driven up the estuary in great quantities.

These occurrences for Storm Bay and the Derwent estuary in the warmer months are roughly in agreement with the observations of other workers previously quoted. There is apparently some spawning in the early summer, though no trace of anything that might be accounted a larva of this species has to date been found in the plankton catches of the research vessel.

V. THE SANDY SPRAT.

Hyperlophus vittatus (Castelnau, 1875).

1. Synonymy, References, and Relationships.

Meletta vittata Castelnau, 1875, p. 46.
Hyperlophus vittatus (Castelnau), McCulloch, 1917, p. 163, Pl. xxix., Figs. 1-2 (synonymy).

The second reference provides a statement of the synonymy and a good list of the literature. To complete this and bring it up to date, the following list is presented:-

Hyperlophus spratelloides (Ogilby), Stead, 1906, pp. 27, 30; Cockerell, 1915, p. 37; Regan, 1922, p. 590.
Hyperlophus copii (Ogilby), Ogilby, 1915, p. 30.
Hyperlophus vittatus (Castelnau), McCulloch, 1921, p.16, Pl. iv, Fig. 52a; Waite, 1921, p. 39, Fig. 56,and 1923, p. 60, Fig. ; McCulloch, 1929, p.40; Stead, 1930, pp. 72, 74, and 1931, pp. 91, 103; Dakin, 1937, pp. 211-212, 215.

The genus *Hyperlophus* contains this one species only. The usage of the name "sandy sprat" for this species in Australia is no doubt based on some supposed similarity to the European sprat to which, however, it has no particularly close relationship.

2. Summary of Previous Knowledge.

The sandy sprat is known from the waters of all the mainland States, although not from any tropical localities. For New South Wales it is said to visit the coasts every year in large shoals, in the summer, though the dates for its occurrences between the years 1893 and 1897 are for the months of March and April. It is also said to shoal in the winter. Another statement is that it is always present in abundance off our ocean beaches, especially in sandy localities. Localities specifically mentioned for its occurrence are Port Stephens, Twofold Bay, Port Jackson, and the Parramatta, Cook's, and George's Rivers. Specimens have been recorded up to about 5 inches in length, though most measurements quoted are rather less, mostly between 3 and 4 inches. Some have been found in a mature condition in February, others were noted to be approaching maturity in June.

Large shoals of this species are stated to visit the bays and sandy beaches of the Queensland southern coast in winter. Moreton Bay and Southport are the localities specifically mentioned. The fish are here said to attain a length of about 4 inches.

In Victoria the sandy sprat is known from the waters around Melbourne, where it is stated to be very abundant at times. The fish are here said to attain a length of about 4 inches.

In South Australia it is stated to be very abundant, to ascend tidal rivers, and to attain a length of 5 inches. A specimen was washed up in Encounter Bay in March, 1886.

Finally, specimens have been recorded from Fremantle in Western Australia, ranging in length from 41 to 56 mm.

3. Distribution Studies.

All the occurrences of sandy sprats that have been noticed during the investigations of the Fisheries Division relate to adult (post-metamorphosis) fishes and have been for New South Wales waters. They may be summarized as follows.

February, 1938, - A few specimens were taken in Middle Harbour, Port Jackson, together with pilchards, and at Ballina (Richmond River entrance), together with anchovies, by officers of the New South Wales Fisheries Department.

October, 1938, - A few were taken by the research vessel with the aid of the submarine light, off Broulee Island.

November, 1938, - Large numbers were caught in beach seine nets near the entrance to Port Hacking, where they were shoaling; shoals of blue sprats were also close at hand, but there was little or no admixture of the two species.

April, 1939, - A few were taken in a beach seine in Port Hacking, together with pilchards, anchovies, and southern herring. A good number were similarly caught in the same month near Ballina: anchovies were also present.

May, 1939, - Several fish were taken in beach seines at Ballina, together with anchovies.

June, 1939, - The "Warreen" with the aid of the submarine light, secured specimens off the entrance to Port Stephens, and near Charlotte Head.

October, 1939, - Some specimens were obtained in beach seine hauls in Port Hacking, together with blue sprats.

December, 1939, - A few specimens were taken in beach seine hauls at the entrance to the Shoalhaven River.

January-February,1940, - During the fishing traverse of the coast north of Sydney previously referred to, small lots of sandy sprats were taken in beach seine hauls, together with southern herring, at Lake Wallis and Taree, and, together with post-larval pilchards and anchovies, at Nambucca Heads. Large samples of specimens caught for bait by local fishermen were also obtained on two occasions at Ballina; in one case an anchovy was present in the sample. During February the "Warreen" secured a few specimens also, in Twofold Bay.

Of these seventeen occurrences fifteen were from inlets or estuaries and the other two (Broulee Island and Charlotte Head) were from places very close to the shore. No sandy sprats have been noticed from the more offshore waters, and no larvae that could be referred to this species have been taken in the plankton catches of the "Warreen".

These facts, together with the observations of previous writers, suggest that this fish is more or less confined to the shallows, inhabiting the bays, estuaries and beach waters. Fishermen at Ballina, who know the species as the "pilchard", state that it is present there all the year round, and if this is so it is very likely to be true also of other localities; in this connection attention may again be drawn to the fact that sandy sprats were definitely present at Ballina in the months of January, February, April, and May, and at Port Hacking in April, October, and November.

4. Length Studies.

The fish measured from all localities, were 1972 in number: they ranged in body length from 22 to 88 mm., i.e. from 29 to 105 mm., or 1.2 to 4.2 inches, in total length. The mean body length was 50.99 mm., i.e. 62.5 mm., or 2.5 inches, in total length. A body length frequency polygon reveals four major modes, at 29, 46, 60, and 73 mm. respectively (i.e. at 37.5, 57, 73, and 87.5 mm., or about 1.5, 2.3, 2.9, and 3.5 inches, in total length), representing four size-groups which may or may not be age-classes. This graph is

not reproduced here, since, owing to the fact that it is based on data secured over a period of more than one year and that the sampling was very irregular, the only other information it gives, that regarding the relative importance of the size-groups, is of no value.

5. Maturity Studies.

The only fish with mature or spent gonads were among those taken from Middle Harbour in February, 1938, and those from Ballina in January and February, 1940: these exhibited maturity stages from III to VII. This, in conjunction with the fact that the fish taken in Port Hacking at the end of November, 1938, ranged in maturity from stages II to IV, suggests that there is some spawning in the summer months in New South Wales. However, in April, 1939, a fish with gonads at stage III was noticed in Port Hacking, and in the same month and the one following stages from I to IV were found in fish from Ballina, suggesting that there is another spawning season in the year, in the autumn or winter. It will be remembered that a similar diversity of opinion upon this point has also been found previously. Unfortunately no further information than this is available, since practically all the fish taken at other times of the year were quite small specimens with gonads at stage I which it might be supposed would not reach first maturity at anything approximating those sizes.

6. Chemistry.

A sample of the fish obtained in Port Hacking in November, 1938, was analysed: the results are presented in Table II.

7. Fishing Methods.

The kind of locality in which this fish is found lends itself very well to the use of beach seine nets to catch them. Inside narrow bays and estuaries, gill nets and traps might also be useful.

VI. THE BLUE SPRAT.

Stolephorus robustus (Ogilby, 1897).

1. Synonymy, References, and Relationships.

The following is a full list of references, arranged according to synonyms:

Spratelloides robustus Ogilby, 1897, p. 64; Lord, 1927, p.12.
Stolephorus robustus (Ogilby), Waite, 1904, p. 12, and 1906, p. 195; Ogilby, 1908b, p. 5; Cockerell, 1915, p. 36; Ogilby, 1916, p. 98; McCulloch, 1920, p. 42; Pl.xi., Fig. 1, and 1921, p. 16, Pl.iv., Fig. 51a; Waite, 1921, p. 38, Fig, 55, and 1923, p. 60, Fig. ; Lord, 1923, p. 63; Lord and Scott, 1924, p. 32; McCulloch and Whitley, 1925, p. 131; Whitley, 1926, p. 228, and 1927, p. 4; Stead, 1930, pp. 68, 70, 74, Fig. ; Whitley, 1932a, p. 270; Dakin, 1937, pp. 211-212; Whitley, 1938, p. 199; Serventy, 1938, p. 308, and 1939, p. 511; Guest and Robertson, 1939, p. 180.
Spratelloides delicatulus Zeitz,(non Bennett), 1908, p. 295.

This species, as well as the next to be discussed, belongs to a different family (Dussumieridae) from the preceding four, which are all placed in the Clupeidae. None of the members of this family are at present of any outstanding commercial importance. The use of the term "blue sprat", like that of "sandy sprat", probably owes its origin to some supposed similarity to the European sprat. It should be noted furthermore that the use of the generic name *Stolephorus* implies here no close connection with many species of anchovy-like fishes that have been described, particularly from the East Indies, under this name, as Australian ichthyologists use it in quite a different sense, following the common opinion (Jordan and Evermann, 1917, p. 67) that the type of *Stolephorus*, while not identifiable with certainty, probably refers to a Dussumieriid species, *Spratelloides argyrotaenia* (Bleeker), rather than to an Engraulid.

2. Summary of Previous Knowledge.

The blue sprat is known from the waters of all Australian States. In New South Wales it is said to visit the coast annually, sometimes in enormous numbers, during the late summer and autumn; but another view is that it is always present in abundance around the entrances of bays and estuaries and in the surface portions of ocean shallows over sandy bottoms, commonly swimming a few feet below the surface but shoaling at the surface in spawning time. The neighbourhoods of Sydney and Port Hacking are the localities specifically mentioned, and the maximum length quoted is 83 mm.

There are several records for Queensland, Southport, Moreton Bay, the Capricorn Islands, Michaelmas Cay, (May to June, 1926), and Low Island (September, 1928), being mentioned by various authors. Large shoals are said to visit the southern part of the coast in the colder months. The fish range in length up to 100 mm.

For Victoria the only definite record is for Queenscliff, in the month of October.

There are records for Tasmania, though the only locality stated is the Derwent River estuary. The fish are stated to range in length up to 2¾ inches.

In South Australia blue sprats have been recorded from St. Vincent's and Spencer (January, 1937) Gulfs. The lengths range up to 70 mm.

Finally they have been recorded from Western Australia, in December, 1936, and at other times, in the Swan River estuary, from 2 to 2½ inches in length.

3. Distribution Studies.

All the occurrences noticed during these investigations relate to adult fishes. Since none of these relate to the offshore investigations of the "Warreen" there is no convenience served by grouping the waters of the States as is done elsewhere for the pilchard, anchovy and maray; the distribution is, therefore, considered separately for the waters of each State.

(a) Queensland.

The only occurrence noted here is for September, 1938, when the research vessel obtained a few specimens by means of the submarine light in the lagoon at Heron Island, in the Capricorns.

(b) New South Wales.

The occurrences here may be summarised thus:

August, 1938, - Several specimens were obtained in Port Hacking with dip-nets.

October, 1938, - A specimen was taken by the "Warreen" by means of the submarine light, in Twofold Bay.

November, 1938, - Blue sprats were taken twice in Port Hacking; on one occasion a few were caught in a gill-net, and on the other when the fish were shoaling, a good catch was made in a beach seine net. The shoals were accompanied by shoals of sandy sprats.

January, 1939, - A good haul of fish was made in a beach seine in Port Hacking.

February, 1939, - Fish were taken in beach seine hauls in Port Hacking on three occasions.

April, 1939, - A specimen was taken in a dip-net in Port Hacking.

September-November, 1939, - A few were taken in beach seine hauls, in each of these three months, in Port Hacking. Sandy sprats were also present on one occasion.

It will be seen that all but one of these records refer to Port Hacking, the other (Twofold Bay) also being from inlet waters. For Port Hacking, the results suggest that the fish are present from August to April, although possibly (since no beach seining work was done in the winter) all through the year, and that it is most abundant in the late spring and summer.

(c) Victoria.

The only records are for December, 1937, when a few fish were obtained, together with anchovies, at Seaford, Port Phillip, and for December, 1939, when some were taken in a beach seine at Reeve's Lagoon, Gippsland Lakes.

(d) Tasmania.

The only records are for April, 1939, when the "Warreen" obtained a few specimens by means of the submarine light off Babel Island, and for November, 1939, when several were taken similarly off Long Island.

(e) South Australia.

In February and March, 1939, a few specimens were obtained at Ceduna, Streaky Bay, and at Antechamber Bay, Kangaroo Island, and in December, 1939, the "Warreen" obtained a specimen with the submarine light off Sandy Point, Yorke Peninsula.

(f) Western Australia.

Some specimens forwarded in April, 1939, were stated to have been caught at Fremantle and subsequently offered for sale in a Perth shop as "whitebait". A few others were caught near Fremantle in February, 1940.

(g) General.

All the above occurrences relate to bays, inlets, or other shallow inshore waters. No blue sprats have been found in the open waters, and on only one occasion were any larvae that could be referred to this species noticed in the plankton collections; these larvae were obtained at an inshore station (St. 92/39) at Cape Jervis, in March, 1939, and have been tentatively identified as those of this species, although the series is not complete enough to describe. Considering these results in conjunction with those of previous workers, therefore, it seems clear that the blue sprat is an inshore fish, to be found in bays, inlets, lagoons, and other shallow sheltered waters.

4. Length Studies.

The fish measured, from all localities, were 621 in number; they ranged in body length from 25 to 78 mm., i.e. from about 30 to 91 mm., or 1.2 to 3.6 inches, in total length.

Of these 621 fish, 503 came from New South Wales alone. The mean body length of these was 62.22 mm., i.e. about 73 mm., or 2.9 inches, in total length. A body length frequency polygon reveals only one size-group of any importance, with a mode at 64 mm., i.e., 75 mm., or about 3 inches, in total length. It might be noted that, except for one specimen, all these were taken in Port Hacking, between August, 1938, and November, 1939. The samples from the other States were too small for any proper length studies, though it may be mentioned

that the means of those samples from Victoria and Western Australia, which were numerically the largest, closely approached that just quoted for New South Wales fish.

5. Maturity Studies.

Fish in mature, spawning, or spent condition (stages V to VII) occurred at Port Phillip in December, 1937; at Long Island in November, 1939; at Reeve's Lagoon and Sandy Point in December, 1939; at Port Hacking in November, 1938, and in January, February, September, and October, 1939; and near Fremantle in February, 1940. Stage IV was noticed, in addition to some of the above, in a specimen from Twofold Bay in October, 1938, and another from Kangaroo Island in February, 1939. All fish taken at other times were at Stage III or less. The spring and summer, therefore, represent a spawning season at least for all States except Queensland, and there is no evidence of any other season for these or any other waters.

6. Chemistry.

A sample of the fish obtained in Port Hacking in November, 1938, was analysed. The results are set out in Table II.

7. Fishing Methods.

This fish can be caught in fine-mesh beach seines and gill-nets. Inside narrow bays traps would probably also be useful.

VII. THE MARAY.

Etrumeus jacksoniensis (Macleay, 1878).

1. Synonymy, References, and Relationships.

The following is a full list of references:-

Etrumeus jacksoniensis Macleay, 1878, p. 36, Pl.iv., Fig. 1; Castlenau, 1878, p.355; Macleay, 1879, p. 382, and 1881, p. 261; Tenison-Woods, 1882, p. 88; Ogilby, 1886, p. 56, and 1893, p. 186; Waite, 1904, p. 12; Zietz, 1908, p.294; McCulloch, 1914, p. 211; Pl. xxix., and 1921, p.16, Pl. iv., Fig. 50a; Waite, 1921, p. 36, Fig. 51, and 1923, p. 57, Fig., McCulloch, 1929, p. 37; Stead, 1930, pp.68, 71, 74, Fig.;Dakin, 1937, pp. 211-212, 215.

This species, like the last, belongs to the family Dussumieridae, none of the members of which are at present of any particular commercial value. The term "maray" is apparently a native name.

2. Summary of Previous Knowledge.

This species has been recorded from mainland coastal waters from New South Wales to Western Australia. For New South Wales it is stated to be a fish of the open waters. Here it has been said to move, perhaps northwards, along the coast in great shoals every winter, though as against this it has also been stated to be uncommon in this State. The only locality specifically mentioned is the neighbourhood of Port Jackson. The maximum length given is 7⅝ inches. In one instance shoaling fish, averaging 16 cm. in length, were found to be immature in the month of August.

The maray has been recorded in Victoria from Port Phillip, where it is stated to be particularly abundant.

For South Australia there is a record from St. Vincent's Gulf. The fish is said to congregate in great shoals at times, and to frequent the offshore waters.

There is in addition a single record from Albany in Western Australia, where a specimen 220 mm. long has been recorded.

3. Development Studies.

Among the fish larvae of the stramin plankton-net collections of the "Warreen", one type, possessing obvious clupeoid characters in respect of the convoluted intestine and posterior position of the anus, but differing sharply from most known clupeoid larvae by virtue of its large pointed head and strongly toothed jaws, was sometimes encountered. These larvae were, however, very similar in general appearance to those described by Delsman (1925) for the East Indian species *Dussumieria hasseltii*, and it was thus regarded as likely that they would prove referable to a member of the same family, the Dussumieridae. The only species of this family known to be common to all the waters from which these larvae were taken - Queensland, New South Wales, and South Australia - are the maray and the blue sprat, and it was, therefore, concluded that the identification lay with one of these species, the former, by virtue of its closer relationship to *Dussumieria*, being regarded as the more likely. This view was subsequently confirmed by sorting out and fitting together the various stages to obtain a fairly clear sequence up to those stages which were old enough to exhibit the very characteristic fin-ray and myotome counts of the maray. This sequence of stages will now be discussed, although it does not represent a complete study of the development, as neither the eggs nor the youngest larvae of this species have yet been recognised.

Since the maray larvae were even less common than those of the anchovy in the plankton catches of the research vessel, the putting together of the development series was a matter of some difficulty, and it was found quite impossible to obtain a complete series from any one locality. Since, however, the results of observation and measurement of series from various quite separate regions in the waters of Queensland, New South Wales, and South Australia showed that there were no significant differences between the sizes and general appearances of the larvae from these regions at any particular developmental stages, it has been held legitimate to describe the development from a series of specimens from three localities in New South Wales and Queensland: these are Sandy Cape (Stations 46/38 and 196/39, *vide* Table I), Coff's Harbour

(Station 201/39) and Port Hacking (Station 30/38). Although, in the main, observations on these larvae were carried out on material from the N100 and N200, some of the specimens described and the figures are from the N70.

At least one type of egg possibly referable to this species has been observed in the plankton, but this part of the development studies cannot be attempted for the present, as so far little search has been made for other possible kinds, and no newly hatched larva, from which it might be possible to identify the egg, has been discovered. The present account begins with a larva in which the yolk-sac has already disappeared.

This specimen, which like the three following comes from Sandy Cape, measures 4.4 mm. in length (Fig.11). It exhibits already the convolutions of the posterior part of the alimentary canal (the intestine), the backward position of the anus, and the crossed muscle fibres of the myotomes, which are all so characteristic of clupeoid larvae, although the latter character is not illustrated in the figures of this or any subsequent stages. The peculiarly large head and the teeth in the widely gaping jaws are also visible at this stage. Pigment is already present in the eyes, and in the form of two series of chromatophores along the ventral border of the body, one lying just dorsal to the anterior part of the gut and one along the under-side of the intestine. The median fin fold is continuous, but the caudal fin, with rays already in evidence, is heterocercal in character. There are no definite traces of pectoral fins. There are 45 pre-anal myotomes.

At a length of 6.0 mm. (Fig. 12) there is little change, except that the pectoral fins have now appeared. This figure shows extremely well the character of the large pointed head, and the wide gape of the toothed jaws.

In the 8.6 mm. larva (Fig. 13) the first traces of both the dorsal and anal fins appear almost simultaneously. At 12.9 mm. (Fig. 14) these fins are fairly sharply marked off from the median fin fold, which henceforth becomes less noticeable, and the caudal is approaching the homocercal type. The distance between the origin of the anterior dorsal ray and the tip of the snout goes about 1.3 times into the total length of the trunk.

When the larva has reached a length of 18.7 mm. (Fig. 15), there can be counted 18 rays in the dorsal and 11 in the anal fin, and at least 53 myotomes. The fin-ray counts as given by various authors reckon from 16 to 21 rays in the dorsal, and 11 to 13 in the anal, and the vertebral count is given as 53, i.e. 52 myotomes.* The dorsal and anal fin-ray counts in this specimen thus agree with those recorded for the maray, while the myotome count is slightly above it;* since, however, this specimen is from Coff's Harbour and no other clupeoid species from New South Wales presents a combination of counts anything like that of the maray, this larva could fairly be referred to this species in spite of the small discrepancy in myotome count.* In this specimen one notices in addition the backward extension, along the full length of the alimentary canal, of the series of chromatophores dorsal to the gut, these later ones being rather deeper lying. The median fin-fold has now disappeared.

In the 24 mm. stage, which was obtained at Port Hacking (Fig. 16), there are to be counted 20 dorsal and 10 anal rays and 53 myotomes, this combination being again very close to that previously recorded for the maray. The head is assuming rather more the characters of the adult of this species. The ventral fins have appeared. The anus has moved gradually slightly forward, and there are now only 41 pre-anal myotomes, though this structure was very close to its adult position in even the first stage described. The dorsal fin has moved slightly forward also, since the distance between the origin of its anterior ray and the tip of the snout now goes about 1.6 times into the total length of the trunk; but as it is immediately opposite the ventrals it is obvious (*vide* Appendix A) that it must move considerably forward yet to attain its adult position. The only other feature of particular interest is the appearance of another series of deep lying chromatophores slightly dorsal to those already described.

These larvae thus seem definitely to be accounted those of the maray, by virtue firstly of their striking resemblance to the closely allied *Dussumieria hasseltii* and secondly of their very characteristic fin-ray and myotome counts, which

* These remarks assume that the vertebral count included the hypural; if it did not the number of myotomes is 53, and there is no discrepancy.

are quite distinct from those of any other clupeoid common to all the waters in which they have been found. It is of interest to notice that the larvae of this species develop faster than those of *D. hasseltii*: in this fish, according to Delsman (loc. cit), pigment does not appear in the eyes until at least past the 6.6 mm. stage, the dorsal and anal fins have not yet appeared at 9.5 mm., and the median fin fold is still obvious at 22 mm.

4. Distribution Studies.

As for the pilchard, we have under this heading to consider the distribution both of adults and of pelagic larvae; it has already been remarked that it was not possible to make any study of eggs.

(a) Adults.

The only records of adults obtained during these investigations are for the waters of New South Wales, Queensland, and Western Australia. The movements of the research vessel in the waters of the first two States named have already been given (see pp. 24,25).

The occurrences may be summarised as follows:

April, 1939, - A few specimens were taken by fishermen in Port Hacking, together with a pilchard.

May, 1939, - The "Warreen" obtained specimens from the stomachs of mackerel tunny off Fraser Island and the Clarence River. In the same month a small lot, mixed with pilchards, was offered for sale on the Sydney fish market. These were probably caught in Port Jackson.

June, 1939, - A single specimen, together with several pilchards, was obtained by the "Warreen" from the stomach of a mackerel tunny taken off Camden Haven.

December-January, 1939-40, - A single specimen was taken in each of these months at Oyster Harbour, near Albany.

Of these seven occurrences, three are from the offshore waters and four from bays; in view of the small number of records it is difficult to say whether the maray should be regarded as more typically a fish of the open sea or by the bays and harbours. For the same reason it is impossible to

arrive at any proper conclusion as to their regional or seasonal distribution, though it will be seen that the records for eastern Australia all refer to waters from Sydney northward into southern Queensland, and are all for the autumn and early winter. It is interesting to note that on three out of the five occasions on which this species was recorded here, it occurred together with the pilchard.

The record for Fraser Island is, it may be noticed, the first for this species from Queensland waters. We now have knowledge of it from all States except Tasmania.

(b) Larvae.

The larvae of the maray were obtained by the "Warreen" from the waters of New South Wales and Queensland and of South Australia, and their occurrences in those two regions will be discussed separately. The distribution of the larvae as shown by the results of the plankton studies are here considered in the same way as that of the pilchard eggs and larvae have already been discussed. The data are presented in full in Table I.

(i) *New South Wales - Queensland.*

Figs. 17, 18, depict the distribution of maray larvae, as determined from the plankton investigations, both qualitatively and quantitatively. Exactly the same procedure as already described for the pilchard has been followed in presenting these results.

From a study of these figures the distribution of these larvae can be summarised for each season of the year under consideration as follows:-

Summer - Occurrence at Port Hacking only (the coast north of Coff's Harbour was not examined): not numerous.

Autumn - Occurrence at Cape Moreton: not numerous.

Winter - Occurrences at Port Hacking; Smoky Cape to Coff's Harbour; and Sandy Cape: most numerous at Coff's Harbour (waters near Montague Island not examined).

Spring - Occurrences at Port Hacking; Cape Hawke; and from Cape Byron to Sandy Cape: not numerous.

From the foregoing it appears that the range of the maray larvae, i.e. of the spawning maray, is from Port Hacking to Sandy Cape, and possibly even further northward. Within

these limits they appear to be generally more common within the edge of the continental shelf, though sometimes found further offshore. They are much rarer than the pilchard larvae and rather less common than those of the anchovy.

The occurrences are very scattered, making it difficult to make any general statement regarding the regional or seasonal distribution in these waters. The main bulk of the recorded occurrences are from the waters of northern New South Wales and southern Queensland, where the larvae seem most numerous and widespread in the winter and spring, though there are some also in the autumn, and there are no data for the summer: for central New South Wales there are occurrences for all seasons except the autumn.

The evidence thus points to a spawning season in the winter and spring in the waters of northern New South Wales and southern Queensland; little spawning seems to occur at any season in the waters of central New South Wales, and even less, or none at all, in the more southern seas. Owing to the relative scantiness of the data, however, these conclusions should not be regarded as final.

(ii) *South Australia.*

As will be seen in Fig. 10 and Table I, maray larvae were taken with those of the pilchard and anchovy in the Investigator Straits in the month of February. This is the only occurrence of these larvae recorded during these investigations for any waters other than those of New South Wales and Queensland. It may be assumed that some spawning occurs in South Australian waters in the late summer.

(c) General.

(i) *New South Wales - Queensland.*

The range of the species, as deduced from the evidence relating to both adults and larvae, is from Port Hacking to Sandy Cape. Within these limits it occurs both in the offshore waters (within and without the edge of the continental shelf) and in the bays and estuaries: in the offshore waters it is apparently rather more common inside the edge of the shelf. It does not appear to be typically a surface shoaling fish, and indeed seems rather rare by comparison with the pilchard and anchovy, though fuller evidence is required on these points. The observations on the larvae suggest that

the maray is much more abundant in the northern waters of New South Wales and the southern waters of Queensland than in seas further south, and that in the former areas there is a spawning season about the winter and spring.

(ii) *South Australia.*

The only evidence relates to the larvae, and this has already been discussed.

(iii) *Western Australia.*

The only evidence relates to the adults, and this has already been discussed.

5. Length Studies.

The specimens measured from all localities, were 25 in number; they ranged in body length from 103 to 182 mm., i.e. from 122 to 216 mm., or about 4.8 to 6.5 inches in total length.

6. Maturity Studies.

Excluding the single specimen taken in May from Queensland waters, whose gonads were at stage I, the great majority of the others (from New South Wales, taken in April, May, and June) were at maturity stages V to VII, mostly the latter: these included the smallest specimen. Since these were mostly from the waters of central New South Wales, there is evidence that some spawning takes place in these areas during the autumn and winter. The specimens taken in Western Australia during the summer months had gonads at stages I or II.

7. Fishing Methods.

Such few specimens of maray as are at present procured for the markets are taken in beach seine nets in the bays and harbours. Too little is known of the manner of its occurrence either in these or in the more open waters to permit the making of any useful suggestions as to how it could be more efficiently taken.

VIII. THE ANCHOVY.

Engraulis australis (White, 1790).

1. Synonymy, References, and Relationships.

Atherina australis White, 1790, p. 296, Pl. opp., Fig. 1.
Engraulis australis (White), McCulloch, 1920, p. 43, Pl. xii., Fig. 1. (Synonymy)

The second of these references provides a good list of the literature and statement of the synonymy. To complete this and bring it up to date, the following list is presented:

Atherina australis (White), Cuvier and Valenciennes, 1835, p. 422; Gray, 1859, p. 41.
Atherina menidia Forster (non Browne, non-binomial), 1794, p. 132, No. 15.
Engraulis encrasicholus, Sherrin (non Linné), 1886, p. 9.
Engraulis antipodum (Gunther), Boulenger, 1900, p. 12; Stead, 1906, pp. 27, 31; Ogilby, 1908a, p. 23; Waite, 1912, p. 317; Cockerell, 1915, p. 37; Phillipps, 1921, p. 118; Jordan and Seale, 1926, p. 392; Young and Thomson, 1927, p. 314; Hardenberg, 1933, pp. 232, 249.
Engraulis antarcticus (Castelnau), Tenison-Woods, 1882, p. 85.
Engraulis australis (White), McCulloch, 1921, p. 15, Pl. iv., Fig. 49a; Waite, 1921, p. 35, Fig. 50; Phillipps and Hodgkinson, 1922, p. 94; Waite, 1923, p. 56. Fig.; Lord, 1923, p. 62; Lord and Scott, 1924, p. 31; McCulloch and Whitley, 1925, p. 132; Whitley, 1926, p. 228; Lord, 1927, p. 12; Phillipps, 1927a, p. 11; 1927b, p. 11; and 1929, p. 345; McCulloch, 1929, p. 42; Stead, 1930, pp. 68, 72, 75, Fig.; Fowler, 1934, p. 387.
Austranchovia australis (White), Whitely, 1931a, p. 311.
Anchoviella mauli Fowler and Bean, 1923, p. 4.
"Anchovy", Jowett and Davies, 1938, pp. 7, 9, 13, 20-21, 23-24, 34-35.

The anchovy belongs to the family Engraulidae, which includes several forms of slight to moderate commercial importance. The best-known species in this connection is the European anchovy, *Engraulis encrasicholus*. Whitley (1931a, p. 311) separates our species generically from *Engraulis* on the grounds that it falls, by virtue of having

its gill membranes united across the isthmus, in a different section of the system proposed for the family by Jordan and Seale (1926, pp. 357-358). The present author has, however, failed to find the membranes united as described, and apparently Jordan and Seale themselves failed similarly, since they include this species (p. 392) in *Engraulis*. Furthermore, Hardenberg (1933, pp. 240-242) shows that many of the characters used by these authors to distinguish different genera are useless for this purpose, and proposes to unite all Engraulid species with oval pelagic eggs (including, by assumption on the basis of other common characters, all species of the genera "*Stolephorus*," *Engraulis*, and *Anchovietla*, as understood by Jordon and Seale, and certainly including, as will shortly be shown, our species) in a single genus. To this he gives the name *Stolephorus*, as having priority over *Engraulis* and *Anchovietla*. It has been shown, however, (Jordan and Evermann, 1917, p. 67) that the type of *Stolephorus*, while not identifiable with certainty, probably refers to a Dussumieriid species, *Spratelloides argyrotaenia* (Bleeker), rather than to an Engraulid, and Australian ichthyologists, as we have already seen, have accordingly so employed it; the generic group proposed by Hardenberg should, therefore, receive the next oldest name, *Engraulis*, and our Australian species should continue to be known as *Engraulis australis*.

2. Summary of Previous Knowledge.

The anchovy has a wide range in Australian and New Zealand waters. It is said to be always present on the coast of New South Wales, generally frequenting the deeper waters of the bays and estuaries; and is also common in the open waters, where it sometimes shoals in great numbers. Generally it swims near the surface or a few fathoms below it, but may go down to depths of 60 or 70 fathoms. The greatest recorded length is 4½ inches.

In the waters of Queensland anchovies have been recorded from Southport, Moreton Bay, and the Capricorn Islands. They visit the former places in large shoals in the winter.

The records for Victoria show that the fish (here called "whitebait") is common, apparently all the year round, in Port Phillip. The maximum recorded length for this locality is 122 mm.

Many authors record it for Tasmania, where it is stated to be common in large shoals offshore, frequently entering the estuaries of the Tamar, Derwent, and Huon Rivers in the summer. The highest length measurement given is 4½ inches.

In South Australia it is stated to be common, although the only specific locality given is in St. Vincent's Gulf.

For Western Australia specimens have been recorded from the Swan River estuary.

The New Zealand records are confined to the east coast of the North Island, viz., in the Bay of Plenty, the mouths of the Thames and Wairoa Rivers, and Hauraki Gulf. In the last-named place they are stated to be commonly taken by trawlers in the spring.

3. Development Studies.

Among the fish larvae of the stramin plankton net collections of the "Warreen", one type, possessing obvious clupeoid characters but quite different from the pilchard and maray, was frequently encountered. On the basis of several characters discussed below - fin-ray and myotome counts, and position of the anus - it was tentatively identified as the anchovy, and this diagnosis was borne out by the discovery of older stages, exhibiting in addition to these characters the very characteristic head profile of the adult anchovy. Eventually, by sorting out and fitting together the various stages, several fairly complete series were obtained for several localities along the Australian coast, sufficient adequately to describe and figure the principal stages in the larval development of this species.

In the main, the description presented are based on a single series from Lacepede Bay (Station 98/39, *vide* Table I), which was chosen because it presented the best continuous series. As, however, this series lacked a specimen with a yolk-sac, this deficiency had to be remedied with a specimen

from Port Stephens (St. 107/38); this was considered legitimate, as the results of observation and measurement of series from various quite separate regions between Lacepede Bay and Sandy Cape showed that there were no significant differences between the sizes and general appearances of the larvae from these regions at any particular stages in their development. It should be stated that, although the main observations on these larvae were carried out on material from the N100 and N200, all the specimens described and figured are from the N70. These were chosen because the fish larvae taken by the latter net were generally in better condition than those from the former, probably owing to the relative fineness of the plankton taken by it.

Although Dakin and Colefax (1933, p. 212, Pl. vii., Fig. 2) had recorded previously, from the neighbourhood of Port Jackson, the occurrence of eggs of the type described for species of anchovy in other seas, no such eggs were found in our stramin net catches. This may have been due to the fact that these eggs, by virtue of their oval shape, would tend to pass through the meshes of such nets. In certain silk net catches (N70 and N50) sorted for the purpose, these eggs were, however, eventually found. At the time of writing only a few such catches have been sorted, and the only ones containing eggs in any quantity have been those from Bustard Bay (St. 44/38): they have, however, also been noticed in collections from Hervey Bay, Cape Moreton, and Lacepede Bay.

(a) The eggs.

The description and figures (Figs. 19, 20) here presented are based on observations on those from Bustard Bay. The eggs are oval, or rather, sausage-shaped, measuring from 1.04 to 1.21 mm. along their longest axis and from 0.50 to 0.55 mm. along their shortest diameter. The membrane is thin, the yolk segmented and without any oil-globule; the yolk-mass itself may be oval or almost spherical and is generally of sufficiently small size to leave a distinct perivitelline space, especially at the poles of the egg. The series studied was not complete enough to include all stages in the development of the embyro; two stages are figured, in the latter of which the eyes and median fin fold of the developing animal are to be seen; no pigment is present.

Specimens of eggs from waters near Sydney, which Professor W. J. Dakin has kindly lent to the author for examination and description, were in all respects very similar to those just described. These eggs ranged in length from 1.04 to 1.23 mm., and in breadth from 0.50 to 0.59 mm., the slight discrepancies between these measurements and those of the eggs from Bustard Bay being probably due to the fact that fewer eggs were available for measurement from the latter locality.

Since, unfortunately, no specimen representing the newly hatched stage has yet been found in any of our material, there is theoretically some difficulty in linking up these eggs with the definitely determined anchovy larvae. However, the very striking elongate-oval shape seems sufficient evidence to base identification upon, since in combination with the segmented yolk this character is confined, among the known types of pelagic fish eggs, to those of the Engraulidae, though not all of these exhibit it. Those species which do show it include the European *Engraulis encrasicholus* (Cunningham, 1896, p. 183, Fig. 95; Ehrenbaum, 1909, p. 371, Fig. 141a; and de Buen, 1931, p. 294, Fig. 1); the Japanese *Engraulis japonicus* (Nishikawa, 1901, pp. 1-12, Pl.); the Californian *Engraulis mordax* (Bolin, 1936, pp. 314-319, Figs. 79, 80); *Anchovia argyrophana* and *A. brownii* from the Atlantic coast of the United States (Kuntz and Radcliffe, 1917, pp. 90, 117-118, Figs. 69-72); *Anchovietta epsetus* from the same region (Hildebrand and Cable, 1930, pp. 388-390, Figs. 2-8); and nine species of "*Stolephorus*" from the Java Sea (Delsman, 1931, pp. 217-243, Fig. 1. *et seq.*, Hardenberg 1933, pp. 249-250). Certainly, if these eggs had only been in Queensland waters, there might be some doubt as to the actual species as there are several other Engraulid possibilities there; but since they have also been taken from the waters of New South Wales and South Australia, where *Engraulis australis* is the only representative of its family, the diagnosis seems beyond doubt. Furthermore, an examination of the ovaries of this species reveals the presence of elongate-oval eggs, which are not found in the ovaries of any of the other marine clupeoids (pilchard, maray, blue and sandy sprat) common to South Australia, New South Wales and Queensland.

The eggs which have thus been identified as those of the Australian anchovy are smaller than those of most of the Engraulid species with similarly shaped eggs. They approach most closely in size those of some of the Javan species of "*Stolephorus*", especially *S. sollingeri*, and also to those of *Engraulis encrasicholus* as described from the Mediterranean.

(b) The Larvae.

As no newly hatched larva has been observed in the plankton catches, the consideration of the development of the anchovy larva must commence with a single specimen in which only the remnants of the yolk are still present (Fig. 21). This specimen, which was taken near Port Stephens, measures 2.9 mm. in length. Pigment is already present in the eyes, and the form of a few chromatophores along the ventral border of the body in the region of the gut, and around the tail region. The mouth is just appearing; the intestine is not convoluted; the median fin fold is continuous, with no sign of any fin-rays developing, and the tail is diphycercal. No traces of pectoral fins are to be seen. The peculiar crossed arrangement of the muscle fibres of the myotomes that is characteristic of clupeoid larvae is noticeable though it is not illustrated in the figures of this and later stages.

At a length of 3.6 mm. (Fig. 22) the yolk is no longer present and several other changes are noted. The pectorals are present, and the caudal fin, with rays already in evidence, is becoming heterocercal in character; the auditory capsule and otoliths are easily seen, and the intestine has assumed the convoluted appearance characteristic of clupeoid larvae. Pigment is present as before, and the dorsal and anal fins have not appeared. The lower jaw is long and protruding, and the nasal profile is concave. The most characteristic feature at this stage, and one by which the larva can quickly be recognised, is the position of the anus; the length of the post-anal part of the trunk (for convenience referred to subsequently as the tail) is about one quarter of the total length of the trunk, and there are 31 preanal myotomes. The specimen figured, like all the ones succeeding it, comes, as has been mentioned, from Lacepede Bay.

In the 4.2 mm. larva (Fig. 23) the first signs of rays (actinotrichia) are present in the dorsal fin. Further pigment spots appear along the post-anal ventral border of the body, and in the opercular region.

At a length of 5.5 mm. (Fig. 24) the anal fin is first noticed. The dorsal is now fairly sharply marked off from the median fin fold, which henceforth becomes less and less noticeable. The distance between the origin of the anterior rays of the dorsal and the tip of the snout goes about 1.5 times into the total trunk length.

When the larva has reached a length of 8.5 mm. (Fig. 25) the caudal fin is approaching the homocercal type, and the dorsal and anal fins have much of their adult form and most if not all of their adult number of rays. At 10.5 mm. the swim-bladder appears, just dorsal to the anterior part of the convoluted intestine: the remnants of the median fin fold have now disappeared.

At the 18 mm. stage (Fig. 26) the ventral fins first appear, and other important changes are seen to have taken place. The profile of the snout is now quite regular, although it has not acquired its adult convexity and does not yet overhand the lower jaw; a further series of chromatophores, deeper lying, is present, dorsal to the swim-bladder and intestine; and the caudal fin is regularly homocercal, although this point is not fully shown in the specimen figured, whose caudal, as is very often the case with plankton-net fish larvae, was damaged. Neither the dorsal fin nor the anus have greatly altered their original positions, though both have shifted slightly forward. In the dorsal fin are to be counted 15, and in the anal 17 rays, while the number of myotomes is 46. The fin-ray counts thus fall within the range described for the anchovy by McCulloch (1920, p. 45), although the myotome count is outside the range he quotes (43 to 45 vertebrae, which represents a myotome count of 42 to 44 if this author counted the hypural, and 43 to 45 if he did not): the present author has, however, found in adult anchovies in South Australian waters, a range in vertebral count (including the hypural) from 43 to 47, representing a range in myotome number from 42 to 46. This combination of counts, cannot however, be taken as absolutely characteristic

of the anchovy, as the same combination has been noted by the author for the sandy sprat.

The identification is, however, placed beyond doubt by reference to the 26 mm. stage (Fig. 27) at which the rounded large snout can be clearly seen to overhang the tip of the lower jaw. The maxillary, too, can clearly be seen extending backwards beyond the eye. The anus is now in approximately the position which it occupies in the adult fish, the length of the tail being approximately one-third of the total length of the trunk, and these are 28 pre-anal myotomes. The dorsal fin, too, has moved forward, the distance between the origin of its anterior rays and the tip of the snout going about 1.7 times into the total length of the trunk; it is not yet, however, in its adult position, as it still occupies much the same position as previously in relation to the anus.

It is not yet possible to determine at what stage this fin occupies its adult situation (i.e. with the origin of its anterior rays just posterior to the origin of the ventrals) for South Australian specimens; but in specimens of post-larval anchovies from Babel Island this situation is reached when the fish is about 45 mm. in total length. The stage at which the silvery lateral bands appear is also as yet unknown for South Australian anchovies; in specimens from Spring Bay, Tasmania, it begins to show up in the form of lateral series of pigment spots, beginning at the posterior end and extending gradually anteriorly, at about a length of 30 mm.

This larval development of the Australian anchovy is very similar to that followed by the other Engraulidae for which this has been worked out (Cunningham, 1896, p. 184; Ehrenbaum, 1909, pp. 371-373, Fig. 141b-141e; de Buen, 1931, pp. 295-299, Figs. 2-4; Nishikawa, 1901, pp. 1-12, Pl.; Bolin, 1936, pp. 319-321, Fig. 81; Kuntz and Radcliffe, 1917, pp. 117-119, Figs. 73-75; Hildebrand and Cable, 1930, pp. 390-393, Figs. 9-15; Delsman, 1929, pp. 275-281, Pl. ii., and 1931, loc. cit; and Kuntz, 1914, pp. 17-19, Figs. 37-45.

4. Distribution Studies.

As for the pilchard and maray, we have under this heading to consider the distribution both of adults and of pelagic larvae; eggs were not found in the plankton catches under consideration.

(a) Adults.

(i) *New South Wales - Queensland.*

The movements of the research vessel in these waters have already been given. The occurrences of anchovies may be summarized as follows:-

February, 1938, - A few specimens were taken, together with sandy sprats, by officers of the New South Wales Fisheries Department, at Ballina.

November, 1938, - A specimen was taken in a beach seine haul in Port Hacking, together with blue and sandy sprats.

April, 1939, - A few were taken in a beach seine haul in Port Hacking, together with pilchards, sandy sprats, and southern herring. In the same month several were caught, together with sandy sprats,in beach seine nets near Ballina.

May, 1939, - Several were taken in beach seine nets together with sandy sprats, at Ballina. A specimen was also obtained from the stomach of a bonito caught by the research vessel off the Solitary Islands.

June, 1939, - A small lot, caught just inside North Head, was offered for sale during the month at the Sydney Fish Market. One specimen was taken, with the aid of the submarine light, by the "Warreen"in Twofold Bay.

August, 1939, - A few specimens were caught in a beach seine net in the estuary of the Wagonga River. Others were obtained by the "Warreen" from the stomachs of bluefin tuna caught between Green Cape and Gabo Island, and off Bateman's Bay.

September, 1939, - A specimen was taken in a beach seine haul in Port Hacking.

October, 1939, - Anchovies were found to be numerous in the stomachs of bluefin tuna taken by the research vessel between Bermagui and Cape Howe, although surface shoals were not seen. A specimen was also taken during the month in a beach seine haul in the Wagonga River, at Narooma, together with pilchards.

November, 1939, - Several specimens were found in the stomachs of bluefin tuna taken by the "Warreen" between Twofold Bay and Cape Howe, and another was obtained from the stomach of a bonito caught off Brush Island. During the month a large haul of anchovies, together with pilchards, was taken in a beach seine net at the Wagonga River.

January-February, 1940, - Small shoals were seen on occasions by the vessel in Twofold Bay, where moderate to good catches were made in beach seines, ring-net, and the lampara (once). Striped tuna (*Katsuwonus pelamis*) caught off Gabo Island had also been feeding on anchovies. During February a specimen was obtained, together with sandy sprats, at Ballina.

It might also be of interest to record that the New South Wales Fisheries Inspector at Greenwell Point, Mr. W. McBride, has reported the occurrence of large shoals of small fish in the Shoalhaven Bight, sometimes entering the Crookhaven River, on numerous occasions from November, 1939, to the present time of writing (May, 1940). No samples have been obtained for identification, but from a description of some specimens volunteered by Inspector McBride to the author some, at any rate, of these fish would almost certainly appear to be anchovies.

Discounting this last, however, we find that out of nineteen occurrences, twelve are from inlets or estuaries and the remainder from the open sea. Few shoals were observed by the research vessel, and, it will be noted, there are no records at all for Queensland waters. The facts indicate that the anchovy is not to be classed strictly as either an offshore or inshore fish, but may inhabit either. Apparently the fish is numerous, both in the open sea (where it is preyed upon by the tunas) and in the inlets, in the waters of southern New South Wales during the spring and summer; elsewhere its occurrence is much less striking. We find it in the Sydney region (Port Jackson - Port Hacking) in the harbours in the months of April, June, September, and November, suggesting that some are present in all seasons. For the northern New South Wales waters, one notes occurrences in the river at Ballina for the months of February, April, and May, and offshore at the Solitary Islands in May also.

(ii) *Victoria - Tasmania.*

The movements of the research vessel in these waters have already been listed. The occurrences here may be summarized thus:-

September, 1937, - Anchovies were common in Port Phillip, where they were caught in beach seines at Chelsea.

December, 1937, - Anchovies were again caught in Port Phillip, at Seaford, with blue sprats. A few specimens were obtained, together with sprats, from the stomachs of barracouta caught in Storm Bay.

May, 1938, - Specimens were obtained from the stomachs of barracouta caught by the "Warreen" off West Sister Island.

June, 1938, - A specimen was obtained from the stomach of a sand flathead (*Platycephalus bassensis*) caught by the vessel in 6 fathoms off Hummock Island.

July, 1938, - Numerous specimens were found in the stomachs of bluefin tuna taken by the vessel near West Sister and Babel Islands.

August, 1938, - Several anchovies were obtained from the stomachs of barracouta caught off Lakes Entrance.

November, 1938, - Specimens were found in the stomachs of barracouta and bluefin tuna caught by the "Warreen" off Babel Island and the Kent Group. This species was also abundant in the bay at St. Helen's and remained so up to March, 1939, and possibly later.

January, 1939, - Specimens were taken from the stomachs of bluefin tuna caught by the "Warreen" off the south-eastern coast of Victoria.

February, 1939, - One adult and several juveniles were obtained from the stomachs of bluefin tuna caught by the ship off Cliffy Island.

April, 1939, - Specimens were obtained from the stomachs of bluefin tuna and salmon (*Arripis trutta*) caught by the ship off Babel Island. The "Warreen" also took specimens by means of the submarine light in Norfolk Bay (in Storm Bay).

August, 1939, - A small lot of fish from Geelong, in Port Phillip, was offered for sale on the Melbourne Fish Market.

Of these sixteen occurrences, only five (Port Phillip - three occurrences, St. Helen's and Norfolk Bay) are from bays or inlets in the strict sense, although none of the others are from places very far from land. It thus appears that the anchovy is rather commoner in the open waters of these states than in those of New South Wales. Furthermore, the occurrences are numerous enough to give some indication of their seasonal distribution. Summarizing the records of the four seasons, we find;

Summer - Anchovies from Port Phillip, the south-eastern coast of Victoria, St. Helen's, and Storm Bay.

Autumn - Anchovies from the Furneaux Islands, St. Helen's and Storm Bay.

Winter - Anchovies from Port Phillip, Lakes Entrance, and the Furneaux Islands.

Spring - Anchovies from Port Phillip, the Kent and Furneaux Islands, and St. Helen's.

These results suggest that this fish is liable to occur in the eastern Bass Strait region, and probably in addition throughout the waters of southern and eastern Victoria and eastern Tasmania, at all times of the year.

(iii) *South Australia.*

The movements of the research ship in these waters have already been summarized. She obtained adult specimens from the stomachs of bluefin tuna in February, 1939, off the Coorong and in the neighbourhood of Fleurieu Peninsula, and similarly in December, 1939, at Antechamber Bay, Kangaroo Island. No conclusions as to the seasonal distribution can thus be drawn. These occurrences were from the open sea, though well within the edge of the continental shelf.

(iv) *Western Australia.*

For the waters of this State we have the following data:-

July, 1938. A single specimen was obtained from the stomach of a tuna (*Kishinoella* sp.) taken off Cape Inscription, Dirk Hartog Island.

November, 1939. A few specimens were obtained in a beach seine haul at Nornalup, on the south coast.

It may be noted that the record for Dirk Hartog Island extends considerably northward of the known range of this species on the coast of Western Australia, the most northern (in fact the only) previous record for those waters being for the Swan River.

(b) Larvae.

As has been already mentioned, the plankton catches of the research vessel have from time to time yielded catches of anchovy larvae. The distribution of these larvae, as shown by the results of the plankton studies, is here considered in the same way as was that of the pilchard eggs and larvae and the maray larvae. The data are presented in full in Table I.

(i) *New South Wales - Queensland.*

Figs. 28, 29, depict the distribution of anchovy larvae, as determined from the plankton investigations, both qualitatively and quantitatively. Exactly the same procedure as already described for the pilchard and maray has been

followed in presenting these results.

From a study of these figures the distribution of these larvae can be summarised for each season of the year under consideration as follows:-

Summer - Range from Cape Howe to Smoky Cape (and possibly further north, as the coast north of Coff's Harbour was not examined); most numerous at Montague Island.

Autumn - Occurrences at Montague Island; Port Hacking; Crowdy Head; and Cape Moreton: nowhere numerous.

Winter - Range from Coff's Harbour to Sandy Cape, nowhere numerous (waters near Montague Island not examined).

Spring - Range from Twofold Bay to Port Hacking, and from Cape Byron (possibly even Coff's Harbour) to Bustard Bay: nowhere numerous.

From the foregoing it appears that the range of the anchovy larvae, i.e. of the spawning anchovy, is from Cape Howe at least as far north as Bustard Bay; it possibly extends even further northward, though the species has not been recorded north of the Capricorn Islands. Within these limits they appear to be more common within the edge of the continental shelf, though sometimes found further offshore. They seem to be much rarer than those of the pilchard though rather more abundant than those of the maray. The quantities found are generally of fairly similar order.

It is difficult to make any general statement regarding the spawning seasons in these waters, especially since the occurrences of larvae are so scattered as to suggest at least two differently behaving populations at different latitudes. For the waters of southern and central New South Wales the peak of spawning seems to be in the summer, since in the year under consideration larvae were more numerous and more general in occurrence there than at any other time. There were occurrences in those waters also in the spring and autumn, but not apparently in the winter. This tallies quite well with the observations of Dakin and Colefax (1933, pp. 212-213), who found anchovy eggs to be most abundant between November and January in the neighbourhood of Sydney. For the waters of northern New South Wales and southern Queensland, the peak seems to be in the spring, though there is no evidence at all available for the summer; there were occurrences

there also in the autumn and winter, mostly in the latter. There is no apparent connection between the occurrences in these two main regions.

Although these results and the conclusions drawn from them have to be regarded no less cautiously than those of similar studies on the pilchard and maray, it seems reasonable to regard them as indicating the approximate condition of the regional and seasonal distribution of the spawning anchovy in these waters.

A few occurrences of post-larval anchovies in these waters may be mentioned. There were found in January, 1940, at Nambucca Heads and in February of the same year at Jervis Bay, Ulladulla, and Twofold Bay. The fish from the first two localities named were associated with post-larval pilchards. The significance of the data is a little doubtful as we do not know exactly how old these fish were. The specimens range up to about 45 mm. in total length.

(ii) *Victoria - Tasmania.*

The evidence regarding the occurrence of anchovy larvae in these waters is very scanty. In the only seas examined at all seasons of the year, i.e. those of the eastern coast of Tasmania and the Furneaux Islands, the only locality at which larvae were found at all was Babel Island, at which such occurrences were noted in the summer and winter, the larvae being much more numerous at the former time. Larvae were also noted off Wilson's Promontory in the spring and off King Island, and in Bass Strait in the autumn (Fig. 9) in small numbers. Apparently some spawning takes place at all seasons.

Some occurrences of post-larvals may be briefly noted here. They were obtained in May and August,1938, from Babel Island, and in January, February, and June, 1939, from Spring Bay, Cliffy Island, and Port Arthur respectively. The specimens taken in May, 1938, and February, 1939, were obtained by the "Warreen" from the stomachs of striped and bluefin tuna respecitvely. The record for August, 1938, was for a small surface shoal, the only definitely proven shoal of anchovies observed by the research vessel in these waters.

(iii) *South Australia.*

As has already been remarked, the only data relating to these waters refer to the months of December, February, and March. At this season, as is shown in Fig. 10, larvae were taken in the plankton nets of the "Warreen" in the Investigator Straits, St. Vincent's Gulf, and Lacepede Bay. These facts indicate that spawning takes place in the Gulfs and shallow offshore waters of eastern South Australia in the summer and early autumn.

Post-larval fish were obtained in February and March from the stomachs of bluefin tuna taken off the Coorong and the North coast of Kangaroo Island.

(c) General.

(i) *New South Wales - Queensland.*

The range of the species from Cape Howe is at least as far north as Bustard Bay. Within these limits it occurs both in the offshore waters, within and without the edge of the continental shelf, and in the bays and estuaries. The evidence available for the adults suggests that it is more typical of the bays and estuaries than the offshore waters, and the results of the plankton studies indicate that, in the spawning condition at least, it is more abundant within the edge of the continental shelf than outside it. It is not apparently as typically a surface-shoaling fish as the pilchard.

The only representative evidence as to the distribution of the species within these waters in the various seasons is that provided by the occurrences of the pelagic larvae, which have already been discussed. The occurrences of the adults are not sufficiently numerous to provide much useful information. Putting both sets of results together, however, it appears that the anchovy occurs to some extent at all seasons (with a spawning peak in summer) in the waters of southern and central New South Wales, and likewise (with a spawning peak probably in spring) in the waters of northern New South Wales and southern Queensland.

(ii) *Victoria - Tasmania.*

It has already been noticed that the occurrences of adults suggest that this fish may occur in the eastern Bass Strait region, and probably throughout the waters of southern

and eastern Victoria and eastern Tasmania, at all seasons of the year. The results in respect of larvae and post-larvae indicate some spawning in winter, spring, and summer for the eastern Bass Strait. The anchovy is apparently here more characteristic of the offshore shallow waters, by comparison with bays and estuaries, than in New South Wales. Only on one occasion has a definitely proved anchovy shoal been noticed during these investigations.

(iii) *South Australia.*

The occurrences of adult fish for these waters established during these investigations are too few to indicate anything beyond the fact that this species may occur in the Gulfs and shallow offshore waters east of Cape Catastrophe during the summer and early autumn. The results of the work on the pelagic larvae confirm this and suggest that this is a spawning period.

(iv) *Western Australia.*

The only evidence relates to adults, and has already been discussed.

5. Length Studies.

The fish measured, from all localities, ranged from larval and post-larval sizes up to 126 mm. in body length, i.e. 143 mm., or about 5.7 inches, in total length. The largest size formerly on record was 122 mm., or about 4.8 inches, in total length.

Length data are available for anchovies from the waters of New South Wales, Victoria, Tasmania, South Australia and Western Australia. The latter two States, being represented in these investigations by only eight and five specimens over post-larval size respectively, are not discussed in this connection, but the other three regions are now considered separately.

(a) New South Wales.

The specimens measured, which were 5272 in number, ranged in body length from 43 to 123 mm., i.e. from 52 to 143 mm., or 2.1 to 5.7 inches, in total length. The mean body length of these is 69.75 mm., i.e. 83 mm., or 3.3 inches, in total

length. This figure is rather biased since, of the total number of fish measured, 4866 were from a single sample, with a mean body length of 69.22 mm.; however, the mean body length of the remaining 406 is not very greatly different, being 75.24 mm., i.e. 89 mm., or about 3.5 inches, in total length. A body length frequency polygon of the total number indicates only one size-group of any importance, with a mode at 67 mm., i.e. 79 mm., or about 3.2 inches, in total length. The fish were all taken between February, 1938, and February, 1940.

(b) Victoria.

Excluding obvious post-larvals, i.e. specimens under 40 mm., in body length, there were only 101 specimens measured from Victorian waters, ranging up to 121 mm., in body length, i.e. 141 mm., or 5.6 inches, in total length. The mean body length is 78.19 mm., i.e. about 92 mm., or nearly 3.7 inches, in total length. The fish were taken between September, 1937, and February, 1939.

(c) Tasmania.

Excluding post-larvals, there were only 52 specimens measured, ranging up to 126 mm., in body length, i.e. 143 mm., or about 5.7 inches, in total length. The mean body length of these fish is 72.48 mm., i.e. 85 mm., or 3.4 inches, in total length. These fish were taken between December, 1937, and June, 1939.

6. Maturity Studies.

Observations as to the maturity of gonads in anchovies were made upon material from New South Wales, Victoria, Tasmania, South Australia, and Western Australia. The results of these will be discussed separately.

(a) New South Wales.

Most of the samples of anchovies taken in the southern waters of the State between August, 1939, and January, 1940, contained several specimens with maturity stages III to VII, indicating that this period, the spring and summer, is a spawning period for anchovies in these waters. This strikingly confirms the results of the studies on larval distribution. Since, however, specimens from Port Jackson exhibited

maturity stages IV to VII in June, 1939, there is apparently some spawning in these waters at least for the winter as well. No other samples were found with gonads at any stage above II.

(b) Victoria.

No specimens from Victorian waters examined for maturity stages have been found to exhibit maturity stages higher than II; these fish, excluding post-larvals, have been taken in the months of August, September, and December.

(c) Tasmania.

Samples of anchovies, which from their size would be likely to contain a fair proportion of mature fish at the spawning season, were taken for examination in the months of November, December, April, June, and July. In the sample for November, taken at St. Helen's, the gonads were at stage IV, and in that for December, taken in Storm Bay, they were mostly at stages V and VI; in the others no stages over II were observed.

(d) South Australia.

The few fish above post-larval size examined for maturity stages from these waters were taken in February and December, 1939. The sample for December, consisting of one specimen only, exhibited stage I, but the February specimens showed stages from I to IV.

(e) Western Australia.

The specimen taken at Dirk Hartog Island in the month of July had gonads at stage III; those from Nornalup in November exhibited stages III-IV. Though the data are very scanty it seems likely that some spawning takes place in the summer at least.

7. Chemistry.

The only analyses performed on this species to date have been one by Jowett and Davies (1938, pp.,20-21, 23-24) on Port Phillip fish taken in September, 1937, and one by this Division on fish taken at Twofold Bay in February, 1940: the results are set out in Table II. The oil content of the Port Phillip fish, which were not apparently approaching sexual maturity, is not very much higher than that of the

other sample, which definitely were approaching maturity, and there was no significant difference in size between the fish in the two lots: further analyses seem, therefore, necessary to clear up the position for this species.*

8. Fishing Methods.

The few anchovies that are caught at present in Australian waters are taken by beach-seining in the bays and estuaries; in such localities gill-nets and traps might also be of use in procuring them. In Holland and Japan the allied species are taken in the inlets by similar means, and in the Mediterranean countries drift-nets are also used in the more open waters (Cunningham, 1896, pp. 182-183; Schepers, 1935, p. 43).

Although the use of purse-seines for shoals does not seem feasible, owing to the fact that such a net with a sufficiently small mesh† would prove extremely difficult to work owing to the weight and resistance to the water, it may be noted that the "Warreen" has on one occasion used her smaller surface-seine, the lampara, with success upon a shoal of anchovies. This was in Twofold Bay, in February, 1940, and was incidentally the only occasion to date on which a significant haul of any species was obtained with this net; about a ton of fish was taken, although four other shots about the same time caught nothing.* All shots were made by day. The records of the research vessel, however, indicate that this species does not shoal at the surface as characteristically as does the pilchard, and hence it is doubtful how useful surface seines can be. Drift-nets of 1 inch mesh would probably prove suitable for catching anchovies in the open sea.

* See Appendix D.

† About $\frac{3}{4}$ inch.

IX. ECONOMIC CONSIERATIONS OF THE GROUP.

The primary considerations in a discussion of the potential economic value of any fish or group of fishes must be firstly utility, and secondly availability. We shall, therefore, consider firstly the possible uses to which each of the species we have already discussed might be put and secondly the extent to which it is likely that these species might be made available for those purposes.

1. Utility.

Throughout the world clupeoid fishes are utilized in four principal ways. These are (*vide* Tressler, 1923, especially chapters 17, 21, and 24):

(a) As canned food:- The great majority of the important species are made use of in this way, particularly outstanding kinds being the North Atlantic and North Pacific herrings, the pilchards or sardines of Europe, Japan, and the Pacific coast of North America, and the North Sea sprat.

(b) As cured food:- The principal species used in this way are the North Atlantic and North Pacific herrings, especially the former. Both species are salt-cured (salted) and the former is extensively smoke-cured (smoked). The European anchovy is also typically salt-cured, though it is by no means as important as the herring in this connection.

(c) As a source of oil and meal:- The menhaden of the Atlantic coast of the United States is used almost exclusively for the manufacture of these by-products; other species which are also important are the North Atlantic and North Pacific herrings, and the pilchards or sardines of Europe, Japan, and the Pacific coast of North America.

(d) As live bait:- The pilchard or sardine of the Pacific coast of North America is used for live bait in the Californian tuna fishery. So, to a less extent, is the Californian anchovy (Godsil, 1938, p.118).

Apart from these might also be mentioned a few minor uses such as fresh food, fish pastes, etc. The four mentioned above are, however, the major lines of utility.

It is now necessary to discuss, from the data already in hand, for which if any of these purposes the seven species of Australian clupeoid fish already considered are likely to be suitable.

It may firstly be noted that for practical purposes none of these species are at present commercially utilized at all in Australia. In New Zealand the pilchard has in the past, especially in the Marlborough Sounds district, supported a small smoking industry and is now in fair demand in the same region as bait for the longline groper fishery (Phillipps, 1929, p.343; New Zealand, 1938, p. 12). In Australia, however, even less use has been made of this species, though small quantities have at times been smoked,made into fish-pastes, or used for bait. Practically no use at all, save possibly for bait, has been made of any other species.

All seven of the species would seem to be theoretically suitable for canning. The close relation of the pilchard and the sprat to species which are extremely important in this regard overseas suggests that these in particular would be particularly useful. (i) The largest pilchards, maray, and possibly southern herring could be made into a pack closely resembling that of the European and American herring and American and Japanese pilchards or sardines; (ii) the smaller fish of these species, together with the sprats, could be packed similarly to the larger French, Portuguese, and Spanish sardines, and the smaller American pilchards; (iii) the blue and sandy sprats could replace the small canned "sardines" of France, Portugal, and Spain (true sardines), Norway (sprats), and the Atlantic coast of Canada and the United States (juvenile herring); (iv) anchovies might also be useful, although these are not canned abroad to any great extent.

As for curing, these species could no doubt all be used for smoking or salting, even though the largest pilchards are generally smaller than the European, Canadian, and American herrings which are so treated overseas. The anchovy of these waters should prove as useful as the European form if similarly salt-cured.

Regarding the possibilities of oil and meal reduction, we have to hand for consideration the results of analyses

for the pilchard, anchovy, and blue and sandy sprats (Table II), though there is no evidence available for the other species. For the pilchard we have seen that, for New South Wales at least, the oil content tends to be low in the spawning seasons and high between them. For that coast we find the estimated yield of oil, for comparatively large fish, is less than a gallon to the ton in the spawning season (winter), while in the summer it goes to over 34 gallons for rather smaller fish and, therefore, probably to a still higher figure for pilchards of comparable size. A similar relation probably operates for the pilchards in Victoria and South Australia, save that there, since the spawning season seems to be the summer, high values would probably be restricted to winter fish; spring and summer pilchards from Port Phillip contain very little more oil than the winter ones from New South Wales, the estimated yield ranging from about 2.5 to 3 gallons per ton.

For the Californian pilchard or sardine the yield of oil per ton of fish in the commercial catch ranges from about 23 to 47 gallons, according to the size of fish, locality,and season (Clark, G. H., 1937). The summer figure for the New South Wales fish is, therefore, fairly comparable with this, and between-spawning catches for other waters would very likely yield similar amounts of oil. The difficulty, as we shall presently notice, is to catch the fish in these between-spawning seasons. In the spawning seasons, the oil yield is far too low to be of any value, though this fact does not of course debar such fish from being potentially useful as a source of meal: indeed it would be an advantage, since there would be no necessity to extract any excess oil from the meal in order to render it fit for feed for stock (an oil content of up to 5 per cent in meal containing 10 per cent moisture being quite satisfactory, cf. Table II), and simpler and cheaper reduction plants would suffice.

For the other species - the anchovy, blue sprat, and sandy sprat - the oil contents appear to be too low for commercial oil reduction, while, except perhaps for the blue sprat, they seem to favour the prospects of an industry based on reduction for fish-meal alone. Further data, however, are desirable here.

Finally as regards live-bait for fisheries based on tuna or other large pelagic species, it might be assumed that at least four of the species we have discussed would be useful for this purpose, since they form under natural conditions the prey of several of these large fishes: these are the pilchard, which as we have seen is preyed upon by the bluefin tuna, mackerel tunny, and bonito;* the anchovy, by the bluefin, striped tuna, bonito, barracouta, and salmon; the sprat, by the barracouta; and the maray, by the mackerel tunny. As regards practical investigations in this direction, the "Warreen" has found anchovies to be very suitable as live bait for striped tuna, since they live well in the bait tank and remain on the surface instead of diving, when thrown into the sea again: in fact this species has proved to be the only kind, among those so far tried as live bait, that is of much use in fishing for tunas. The firm of Kangaroo Investigations Pty. Ltd. have attempted to use pilchards as live bait for bluefin tuna in South Australian waters, but were never able (probably because of overcrowding and the poor shape - rectangular rather than square - of the bait tank used) to keep them alive long enough. The "Warreen" has had a simila experience with the sprat, though not for similar reasons.†

The other three species, the southern herring, blue sprat, and sandy sprat are typical of more inshore waters: one would not, therefore, expect them to form in nature a food of any of the large offshore fishes, and so their utility as live bait is a matter of rather more doubt than for the others.

It is now necessary to attempt to show to what extent these various species of fishes could be made available for the purposes of any of the above kinds of commercial activity.

2. Availability.

The availability of a species depends in practice on three main factors, its abundance, its distribution, and the means required to catch it. The second factor comprises both regional and seasonal distribution, both of which, especially the former, must largely determine the fishing methods to be employed. This therefore represents perhaps

* Also by salmon and barracouta, cf. Appendix D.

† See Appendix D for further discussion of bait fishing.

the most convenient heading under which to discuss the availability of the different species.

Furthermore, since regional is probably of more fundamental importance than seasonal distribution, it will be found more convenient to discuss all other factors under this heading. It is next important to decide in what way such a discussion based on regional distribution is to be conducted - whether on the basis of broad geographical features, such as open seas, gulfs, bays, and estuaries, which are common to all or most parts of the Australian coastline, or on the basis of specifically district sectors of the area under consideration. As no less than three out of the seven clupeoid species under consideration, the pilchard, anchovy, and blue sprat, are known to occur throughout the entire area under consideration, while two others, the maray and sandy sprat, are only slightly more confined in their distribution, it seems obvious that the same broad conclusions in respect of most of our species can be drawn for the entire area, and our discussion is therefore based upon a consideration of broad geographical features.

This has been done by distinguishing three different types of environment, and discussing separately the relations of the various species to each. There are :

(a) The offshore waters: By these are meant the waters of the open sea generally, both within and without the edge of the continental shelf.

(b) The gulf waters: This type of environment is hardly common to all sectors of the Australian coastline, since it is meant to include very large open gulfs and bays, in which the characters of both the open sea and of bays and inlets properly speaking are encountered. The best examples of this type of environment in the waters of south-eastern Australia are the Spencer and St. Vincent's Gulfs; Hervey Bay might be taken as another instance, though on a rather smaller scale.

(c) The inshore waters: These include all more or less circumscribed small bodies of water, such as the typical bays, harbours and estuaries of the Australian coastline, as well as the waters of the ocean beaches close inshore, i.e. all waters

at a depth of about 15 fathoms or less.

Having thus briefly defined the three types of environment one can now pass to a further discussion of the relations of clupeoid fish species to each, and their availability therein.

(a) The Offshore Waters.*

Of the seven clupeoid species already discussed, the one most characteristic of these waters is the pilchard. Indeed, as we have seen, this fish is much more typical of the open sea than the inshore waters, into which it apparently only comes sporadically, although it also ranges well into the gulf waters.

Our knowledge of this fish in the offshore waters relates in the main to the waters of New South Wales and southern Queensland, where, as has been seen, it is apparently present in at least the waters of central New South Wales all the year round, but does not appear with much constancy in the form of surface shoals save between the months of May and September, when the fish are mostly spawning or spent.

The fact that the pilchard forms surface shoals at once suggests the use of large surface seine nets, such as the purse-seine or the lampara of the Californian pilchard fishery, to capture it; and indeed for an industry envisaging the use of very large supplies, such as an oil and meal reduction enterprise would perforce have to do, some method such as this would be essential. It has been shown, however, that owing to the much smaller size of the fish in these waters, purse-seine nets with a mesh similar to those used in California could not be expected to retain the catch, except in an undesirable meshed condition, and it is doubtful whether a net as large, but with small enough mesh (say $\frac{3}{4}$ to 1 inch) for these pilchards, could be easily worked on account of the increased weight and resistance to the water which a diminution in the mesh would entail. We have also seen that the lampara net, while of small enough mesh, has so far proved rather disappointing for the capture of pilchards in these waters owing to their shyness and the fact that they occur more typically by day than by night.* Another great drawback to the use of nets of this type is the fact that they require fairly good weather for their manipulation, while at the season at which these fish shoal

* Appendix D should be read in conjunction with this section, and with that on the gulf waters, as it provides some valuable later information.

in New South Wales and Queensland waters much of the weather is typically indifferent or bad.

It must also be admitted that even at this season pilchard shoals do not seem to occur in any overwhelming abundance. The following is a summary of the observations of the research vessel "Warreen" in respect of her survey of the northern coast of New South Wales (between Port Jackson and Cape Byron) for pilchard shoals during the five months May to September, inclusive, of 1939:

Number of days spent on the coast	50
" " " of bad weather	16 +
" " " of good to moderate weather ..	34 -
" " " on which pilchard shoals seen ..	11

No shoals were seen at all on the southern coast of New South Wales (between Port Jackson and Cape Howe), the results of a similar survey during the same months being as follows:-

Number of days spent on the coast	13
" " " of bad weather	3
" " " of good to moderate weather ..	10
" " " on which pilchard shoals seen ..	0

Considering that, as deduced from the results of the studies on the distribution of pilchard larvae, the main bulk of the occurrences of pilchards seem to be in waters inside the edge of the continental shelf, i.e., within a strip of water averaging only about 15 miles in breadth, the observations of the "Warreen", which was specifically searching for pilchards and followed up every clue that it was considered might lead to their discovery, should be admitted as a reasonably adequate sampling of these waters in respect of pilchard shoals; and it is obvious that these observations indicate no more than moderate abundance of these shoals. These results are also important as regards the weather conditions to be expected during the pilchard season, indicating that roughly between a quarter and a third of the active season might be expected to be useless for surface-seine fishing.

Finally it may be repeated that the pilchards occurring at this season are mainly spawning or spent fish, and that, apparently on this account, their oil content even for the largest fish is extremely low; while between spawnings, when

the oil content is much higher, the fish do not occur so regularly at the surface. Further, since the fish cannot apparently be easily taken in purse-seine and lampara nets (the only types of net which would catch them in large enough quantities for an oil and meal reduction industry), and since, even if this were not so, the use of such nets would be impossible over at least a quarter of the season owing to bad weather, it would seem that the prospects for the immediate commercial utilization of these fish in New South Wales - Queensland waters for the purposes of reduction into oil and meal are not at all promising. Some reservation must however be made about the efficiency of the lampara,* which as we have noticed has had some success with these fish in other waters, and with other fish in these waters. The second two factors, with the same reservation, also militate against a fishery for this species to use as live bait. The only way in which it seems likely at present that any considerable catch could be made of the pilchard from the offshore waters of these States is by the use of drift-nets; as has been noted, this is the principal method employed to catch the allied species in European waters, and it is also used for catching the pilchard of Japan. Such nets could have mesh sizes ranging from 1¼ to 1½ inch. Drift nets would have the advantage of being able to take fish at times when the weather would preclude the working of large seines, and should also, in some waters at least, take fish all the year round. On the other hand they would certainly not catch large enough quantities to meet the requirements of reduction plants, nor would their catch be suitable for use as live bait; they could however be expected to provide a steady if moderate supply of fish suitable for canning and perhaps for curing purposes.

Elsewhere, relatively little is known of the offshore occurrence of the pilchard, though sometimes it occurs in surface shoals in South Australian waters in the summer and early autumn, and probably in Victorian and some Tasmanian waters at about the same time. It may indeed occur in these waters at all seasons. The fact that the surface shoaling season here appears to be in the summer and autumn suggests that a lower percentage of bad weather might be encountered during the season. Nevertheless there is nothing to suggest that surface seine nets would prove more useful here than in

* See Appendix D.

the waters just considered, while, on the other hand, drift-nets would probably prove no less suitable than in those seas. The oil content is also apparently very low in the shoaling season. If pilchards could be caught for live bait they would be more valuable for the tuna fishery in these waters, especially those of South Australia, than in New South Wales, as there the pilchard season coincides with the tuna season, while in the waters of New South Wales it precedes the appearance of tuna by some months.*

Apart from the pilchard, we have also noticed that the anchovy, maray, and probably also the sprat tend to occur in these offshore waters, though none of them are as conspicuous there as the pilchard. By far the most common and widespread of these appears to be the anchovy, which occurs throughout the waters of south-eastern Australia, though apparently not as typically in shoals as the pilchard. The seasons at which it occurs in the various waters are not yet fully known, though there is some evidence to suggest that in some at least of the waters of Victoria and Tasmania it may occur at all seasons, and there seems to be a definite season for the New South Wales south coast in the spring and summer; since this is also the tuna season there, this species would be very valuable, if it could be regularly caught, for live bait. The fish is much smaller than the pilchard, and could not be retained, except in an undesirable meshed state, in large quantities by a surface seine net with a mesh over $\frac{3}{4}$ inch: it will be recalled that a catch was once taken in the lampara. Drift-nets with a mesh size of about $\frac{1}{2}$ to $\frac{3}{4}$ inch might be useful in these waters. Regarding the other two species there is insufficient evidence as to abundance, distribution, and manner of occurrence to suggest in what way, if any, these fish could be made available.

(b) <u>The Gulf Waters.</u>*

In the open waters of the Spencer and St. Vincent's Gulfs (including the adjacent Straits) the pilchard, anchovy, and maray are known to occur, while around the beaches and islands, and in the smaller bays, blue (and probably sandy) sprats are to be found.

These waters thus present a combination of the occurrences of the offshore and inshore waters.

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* Refer to Appendix D.

The only information obtained regarding these gulfs as a result of these investigations attests to the fairly general occurrences of pilchards and anchovies, especially the former in these gulf waters during the summer and autumn, i.e. at about the same season as they apparently occur in the offshore waters of South Australia. Here the season for these species coincides with that for tuna, which naturally feed on them. The pilchards, at least, tend to appear in surface shoals. These shoals, however, present the same difficulties as regards capture in surface seine nets, as they are daylight fish, very shy, and of apparently no larger size, and they probably (in view of this size and the fact that they are spawning at this time) have no greater oil content than those of New South Wales. It seems, therefore, that the possibilities of using the pilchard of these waters for live bait or oil and meal reduction are not promising, though in view of the fact that some catches with the lampara have been made here the question of the efficiency of this net is still obscure, and it may yet prove to be a means of taking fish which could be used for bait.* It may be noted that if surface seining were useful it would probably be possible over a greater part of the season than in New South Wales, since more good weather could be expected in the sheltered waters of the Gulfs in the summer and autumn than has been found in the open seas off the New South Wales coast in the winter. Once again drifting seems the most hopeful avenue for obtaining pilchards (and anchovies) for commercial purposes,* though fish so caught would only be of use, in the main, for canning and curing.

Any kind of clupeoid fish, if it could be caught in the proper manner in these waters in the summer and autumn, would be of great use as live bait for tuna; if no way can be found of taking the more offshore types, attempts should be made to take such species as the blue sprat, which is presumably common around the bays, islands, and beaches.

(c) <u>The Inshore Waters</u>.

There is evidence that all seven of the species previously discussed may enter the inshore waters, but it seems that the occurrences of pilchards here are definitely much fewer and more sporadic than further offshore,* while the true

* See Appendix D.

behaviour in respect of this environment of the maray and sprat is still very insufficiently understood. Of the four other species, the anchovy occurs not uncommonly in these waters as well as offshore, and the southern herring and blue and sandy sprats appear to be practically confined to the shallows; these types, therefore, are the principal ones to consider.

It must be borne in mind that the environments of inshore waters, especially fairly enclosed ones like those of bays and estuaries, tend by their very nature to become influenced by factors which are often very different in even closely adjacent areas; that is to say, one must expect to find each particular sector of inshore waters possessing a certain individuality in respect of its natural environment, of which, of course, the fish form a part. Hence generalizations regarding the occurrences of behaviour of fish in several such sectors, even ones quite close to one another, are not as safely made as they can be for the open sea; and such conclusions as are put forward cannot be regarded as applying to any particular sector of inshore waters until these have been specifically checked for each locality. Nevertheless it seems fair to say that these four clupeoid species, the anchovy, herring, blue sprat, and sandy sprat, are likely to be found in the inshore waters of the States in which they have been recorded at most, if not all seasons of the year. Within such waters it is possible to take them in at least fair quantities in beach seines, and gill nets and traps would also probably prove useful. The fish so caught should be suitable for canning, curing, the manufacture of pastes, and probably also for live bait. The oil content, however, is apparently not high, and furthermore it is doubtful whether these fish could be constantly procured in large enough quantities to support a reduction industry; if they were, intense exploitation would probably have the effect of exterminating the species within a relatively short time, as it is probable, in the case of the blue and sandy sprats at least, that little replenishment of stocks would take place from outside the particular waters in question. It must however be emphasised that these conclusions are not yet fully proven and that in any case they should not be assumed to be true of any particular piece of inshore water until that area has been thoroughly examined, at least in respect

of what species occur in it. The determination of what gear is to be used in such waters, too, depends very largely on the nature of the waters, and on the behaviour of the fish in them.

It might be noticed in respect of the possible use of inshore fishes for live bait that it is possible that other small species besides clupeoids might be useful in this regard. The Atherinid fishes, such as the atherines and hardy-heads, which seem to frequent many inshore waters at most if not all seasons of the year, are a group which it seems worth while to investigate from this viewpoint.

3. General Summary.

We can now summarize as follows the position in respect of the economic value of the clupeoid fishes of south-eastern Australia:

(a) Several species, which when packed would compare in size with at least the small and medium-sized packs of similar fish imported into Australia, are suitable for canning purposes. The smaller-sized fish are available in the inshore waters (blue and sandy sprats, and anchovies* to some extent) and could be taken in beach seines, gill nets, or traps, probably at all times; the same applies to the southern herring which however is a rather larger fish. The other fish of larger size (pilchards, anchovies to some extent, and possibly other species) are available, probably at all times, in at least some offshore and gulf waters, and could probably be captured in drift nets; it is possible, although the position is rather doubtful, that they could also be taken in certain waters during certain rather restricted seasons by means of the lampara or some similar net. †

(b) The same conclusions apply to curing.

(c) The only species, so far as is known at present, that seems likely to be useful for both oil and meal reduction is the pilchard, and there would probably be difficulties in making the fish available in sufficient quantities. The question of availability in regard to use for meal alone is doubtful only in so far as the efficiency of the lampara net

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* And pilchards, cf. Appendix D.

† See Appendix D.

or other surface seine is doubtful, but this doubt is, as we have seen, a fairly considerable one.* In regard to oil the position is much worse, since added to this doubt there is the fact that the fish do not shoal so much at the surface at the season when their oil content is high, which means that large quantities could probably not be obtained regularly even if the lampara or similar gear could take them. The anchovy and sandy sprat at least would also probably be quite useful for reduction into meal alone, although again it would be probably difficult to make them available in large quantities.

(d) The species of the inshore waters could be made available for use as <u>live bait</u> by means of beach seines and traps; the larger offshore species, which would probably generally speaking be more useful for this purpose, are not likely to be readily available unless the lampara or some similar net can be worked to take them.*

X. PROGRAMME FOR FUTURE INVESTIGATIONS.

Based on consideration of all that has been previously said, especially in the last section, the programme of the future clupeoid investigations should as far as possible comprise the following:-

1. The continuation of the studies of regional and seasonal distribution of the clupeoid species, including the further testing out of drift-nets in the offshore waters concurrently with further trials of surface seines.

2. Further biological and chemical investigations, on broad lines, of the clupeoid species, including studies of age-determination and rate of growth.

3. The intensification of work upon the species of the inshore waters, to establish or confirm for as many individual localities as possible the occurrences and behaviour of these species and the methods deemed useful for catching them.

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* See Appendix D.

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APPENDIX A.

KEY TO SPECIES OF MARINE AND ESTUARINE CLUPEOID FISHES IN AUSTRALIAN TEMPERATE WATERS.

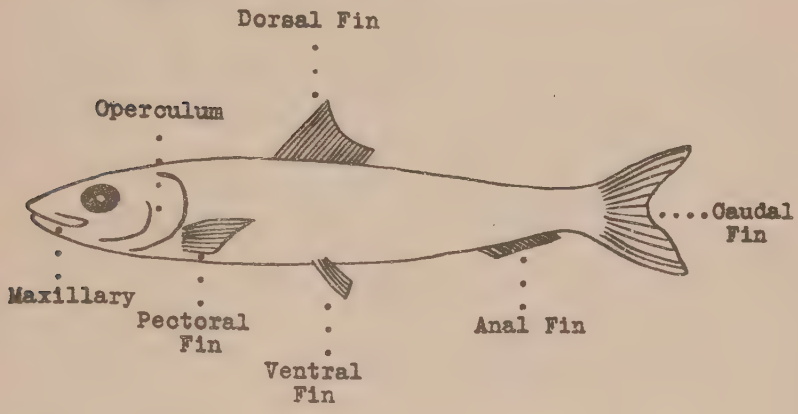

Diagram of a clupeoid fish, showing parts referred to in key below.

This key includes all the species which have been satisfactorily recorded from localities south of the Tropic of Capricorn.

Fishes with one dorsal fin only, which is fairly short, and without stiff spines; body scaly, no lateral line, 8 or 9 rays in the ventrals, never exceeding 18 inches in length, often much shorter.

A. Mouth very large with snout projecting beyond it; maxillary extending backwards beyond the eye.

B. Belly smooth; about 15-20 rays in anal fin. *Engraulis australis.*

BB. Belly partly rough, serrated; about 30-35 rays in anal fin.

C. Dorsal fin midway between tip of snout and root of caudal fin. .....*Anchovietla nasuta*

CC. Dorsal fin nearer to tip of snout than to root of caudal fin. .....*Anchovietla aestuaria*

A. Mouth small, the snout not projecting, the maxillary not extending backwards beyond the eye.

B. Belly smooth, rounded.

C. Dorsal fin in front of the ventrals.....*Etrumeus jacksoniensis*

CC. Dorsal fin opposite the ventrals .....*Stolephorus robustus*

BB. Belly rough, serrated. compressed.

C. Back rough, serrated, in front of the dorsal fin.

D. Ventral fins just in front of the dorsal fin.

E. Anal fin commencing behind last ray of dorsal. .... *Hyperlophus vittatus*

EE. Anal fin commencing below last ray of dorsal. .... *Hyperlophus translucidus*

DD. Ventral fins below the dorsal fin. .... *Potamalosa novae-hollandiae*

CC. Back smooth.

D. Last rays of dorsal fin not elongated.

E. Ventral fins below first rays of dorsal fin. .... *Clupea bassensis*

EE. Ventral fins below middle rays of dorsal fin.

F. Operculum with several radiating grooves. .... *Sardinops neopilchardus*

FF. Operculum smooth

G. Body not laterally compressed, elongate; depth about $\frac{1}{4}$ of length from tip of snout to root of caudal fin; last two rays of anal fin much longer than the third last .... *Sardinella postera*

GG. Body laterally compressed, more rounded in profile; depth about 1/3 of length from tip of snout to root of caudal fin; last two rays of anal fin not noticeably longer than the third last ..... *Harengula castelnaui*

DD. Last rays of dorsal fin elongated. *Nematalosa* sp. or spp. (relations of species dubious).

APPENDIX B.

COMMON NAMES AND DISTRIBUTION OF MARINE AND ESTUARINE CLUPEOID FISHES IN AUSTRALIAN TEMPERATE WATERS.

Scientific Name	Common Name	Distribution as known
Engraulis australis	Anchovy	Queensland, New South Wales Victoria, Tasmania, South Australia, Western Australia
Anchoviella nasuta		Queensland.
Anchoviella aestuaria		Queensland.
Etrumeus jacksoniensis	Maray	Queensland, New South Wales, Victoria, South Australia, Western Australia.
Stolephorus robustus	Blue sprat	Queensland, New South Wales, Victoria, Tasmania, South Australia, Western Australia.
Hyperlophus vittatus	Sandy sprat	Queensland, New South Wales, Victoria, South Australia, Western Australia.
Hyperlophus translucidus		Queensland, New South Wales.
Potamalosa novae - hollandiae	Freshwater herring	New South Wales, Victoria, (freshwater, but may possibly come into the estuaries).
Clupea bassensis	Sprat	Tasmania, Sth. Australia.
Sardinops neopilchardus	Pilchard	Queensland, New South Wales, Victoria, Tasmania, South Australia, Western Australia.
Sardinella postera	Scaly mackerel	Western Australia.
Harengula castelnaui	Southern herring	Queensland, New South Wales.
Nematalosa sp. or spp.	Hairback herring Bony bream Tukari	Queensland, New South Wales, Western Australia (possibly estuarine in South Australia).

APPENDIX C.

NOTES ON THE "SCALY MACKEREL" OF WESTERN AUSTRALIA.

Sardinella postera (Whitley, 1931).

Amblygaster posterus Whitley, 1931b, p. 144.
Clupanodon neopilchardus, Waite (non Steindachner), 1905, p. 58; Alexander, 1922, p. 479.
Sardinops neopilchardus, Serventy (non Steindachner), 1938, pp. 299-300.

The genus *Amblygaster* Bleeker, 1849, to which Whitley refers this species, is usually regarded at the present day as a synonym of *Sardinella* Cuvier and Valenciennes, 1847 (*vide* Jordan and Evermann, 1919, p. 240). Thus Regan (1917b) does not regard it as a valid genus, and includes its type (*A. clupeoides*) in *Sardinella*. However, Chabanaud (1926, pp. 161-163) continues to recognize these two genera as separate, the main distinguishing features according to him being the ventral fin-ray count (nine in *Sardinella*, eight in *Amblygaster*), the character and number of the gill-rakers (slender and numerous in *Sardinella*, but short, robust and rather few in *Amblygaster*) and the character of the glossohyal (entire in *Sardinella*, divided in *Amblygaster*).

The single specimen studied by this author would be referable to *Sardinella* on the basis of the first two of these three characters, but to *Amblygaster* on that of the third. One is obliged, therefore, to refer to this species in any case to *Sardinella* while noting that the status of *Amblygaster* as a separate genus is not improved by the breakdown of a part of the combination of characters suggested for distinguishing it. Actually this form very closely approaches the type of *Sardinella*, *S. aurita*, and its close relation *S. longiceps* (Regan, 1917b), and may eventually prove to be identical with one or other of these species. It agrees in most respects with *S. aurita* save that its gillraker count for the lower limb of the first arch (c. 178, taken from the author's specimen) is closer to that of *S. longiceps*; the longitudinal scale count, however, which is 40-45, seems to distinguish it from both these forms, in which the count is about 46-48.

The specimens from which Whitley described the species were all from the Fremantle district, whereas the specimen in the possession of the author was taken in a beach seine haul at Oyster Harbour, near Albany, early in December, 1939. It has already been pointed out in the text that all the published records of the pilchard in Western Australia refer instead to this species, for which reason they have been included in the synonymy above: these records refer to Fremantle, the Swan River estuary, and Houtman's Abrolhos. The fish has, therefore, a fairly extensive distribution in south-western Australia, ranging at least from Albany to the Abrolhos. It is apparently fairly well known to fishermen under the name of "scaly mackerel." According to various reports from fishermen and fisheries inspectors it is common in the Swan River estuary and occurs at Busselton in shoals during most of the year; it was also said to be numerous in Oyster Harbour in December, 1939.

As to size, Whitley notes that his six specimens ranged from 7¾ to 8¾ inches in total length, that of the largest being equivalent to 176 mm. in body (standard) length. The specimen from Oyster Harbour has a damaged caudal fin but as the body length is 180 mm. it may be assumed that the total length was in the vicinity of 9 inches, i.e. greater than the maximum total length recorded in Australia for any other clupeoid species during these investigations.

APPENDIX D.

OBSERVATIONS ON CLUPEOID FISHES MADE SINCE FEBRUARY, 1940.

In this section observations made between the end of February, 1940, where the record in the main text ends, and the end of November, 1940, are briefly summarised and discussed.

1. PILCHARD.

In New South Wales waters, the usual shoals of spawning (non-oily) fish were present, principally offshore, between May and September. During September, October, and November, however, pilchards were also fairly numerous, mostly in bays or otherwise close to the land, along the coast from Twofold Bay to Port Stephens (and possibly further north, though these waters were not visited). These fish were, however, mostly quite small and immature, ranging from about 2 to 4 inches in total length. It is hoped to discuss this data more fully in a subsequent publication, but for the moment it can be said that it seems likely from this and other evidence that at this stage in their life history pilchards are much more characteristic of inshore than offshore waters, whereas in their later life, as already pointed out, the reverse is the case: probably after being spawned at sea the young postlarvals move in towards the land, remain there until about 4 inches in length, and then return to the open sea for good. Whether or not this explanation is correct it seems clear that, unless extremely abnormal conditions prevail this year, the pilchard season on this coast lasts for at least two months longer than was previously supposed, the extension being however almost entirely in respect of smaller immature fish, in more inshore waters, than during

the main (winter) season. This fact is of the utmost importance, particularly from the point of view of live-bait fishing for tuna, since this extension of the pilchard season coincides with the first part, at least, of the tuna season in the waters south of Sydney, and so suggests a source of live-bait, in addition to the anchovy, for use in tuna fishing at this time: and indeed it is shown here that these pilchards have already been proved suitable as tuna bait.

The position in respect of fishing gear for pilchards has also become slightly clearer since the main text was written (see pp. 45-57, 96-100). It was there stated that although the lampara net had had some success with pilchards in South Australia (see also below) it had on other occasions failed to take the fish, owing to the fact that they would escape, either by diving or swimming through the large-meshed wings of the net; consequently it was suggested that althougn the position was obscure, the prospects of using this type of gear were not very promising.

Excluding the four catches made with the lampara in South Australia by the Kangaroo Investigations' vessel "Corwa", (see p. 46) and considering the experience with pilchards of the "Warreen" alone, we recall firstly that her lampara was shot four times upon pilchards during 1939, with no positive result (see p. 46); all were daytime shots. Since then, during 1940, she has shot it eight times by day and six times by night, upon pilchards or presumed pilchards; one of the daytime shots caught half a ton of fish, and one of the night ones caught two tons. In all, therefore, she has had twelve day shots, one of which was fairly successful, and six night ones, one of which was quite successful. While still not conclusive, these results strongly suggest that, while the lampara is never likely to prove an efficient means of taking pilchards regularly in the daytime, it has possibilities for night shots. On the occasion of the very successful night shot referred to, the fish were milling quietly around on the surface, not being harried by seabirds, porpoises, or other predators; and while this desirable state of things is not bound to occur always at night, and may on the other hand occur sometimes by day (as was probably the

the case on the occasions of the successful daylight catches of the "Warreen" and "Corwa"), it is probably much more likely to occur by night than by day. Furthermore, on this occasion the pilchards did not dash through the wings as they have often done, but retreated into the bag instead; the reason was probably that the wings, being brightly luminescent on account of the small organisms disturbed by the motion of hauling, tended to deter the fish from passing through them, but caused them to retreat instead into the dark bag of the net: if this was so, it provides another explanation of the success of this haul, and another reason for supposing that night hauls would be on the whole more successful. There is also the point to consider that in the night time it is presumably far easier for the vessel and its gear to approach and encircle the fish without scaring them.

Unfortunately, it still appears that pilchard shoals are less commonly seen by night than by day, and that moonlight nights are virtually useless for seeking them since the luminescence of the shoals cannot be readily detected. Nevertheless, the position of the lampara appears in a slightly more favourable light. However, in view of the importance of the matter and the obviously severe limitations to the use of the lampara, it has been decided to make further trials with other types of surface seine nets. To this end the upper sections of the "Warreen's" 1-3/8 inch mesh purse-seine net (see p. 46) have been replaced with 1 inch mesh webbing, and it is proposed to try out this gear shortly, notwithstanding the fact that, on account of the increased weight and resistance to the water, it will undoubtedly be rather more difficult to work: however, it is also intended to procure a smaller and lighter 1 inch mesh net of the general purse-seine type. These types of surface seines, having no large mesh wings and capable of being closed below before hauling, might be quite successful in the daytime as well as at night.

Owing to the necessity of testing the lampara and to pressure of work in other fields, drift nets were not tested during the main 1940 pilchard season. There seems no reason to doubt that they would have yielded moderate catches, but

naturally any type of surface seine, if it can be used, would catch far greater quantities than drift nets. They would also take the catch alive, which is the only way it would be of much use for tuna fishing.

Pilchards have been tried out as live-bait for tuna pole-fishing on two occasions since the opening of the tuna season on the southern New South Wales coast. During October, the bait tank was filled with small pilchards taken with the "ring net" at Port Stephens, and these fish were taken some 350 miles to the bluefin tuna grounds in the Montague Island-Merimbula region. The tuna did not bite on this occasion (apparently being full of pilchards already), and the experiment was a failure except that it proved (cf. p. 94) that the fish lived well in the bait tank. Later during the same month the tank was filled with small pilchards caught in the lampara at Jervis Bay, and a trial made with them upon tuna near Brush Island yielded a fair catch on poles.

The prospects for reduction of pilchards for oil remains unpromising. Further analyses have confirmed the fact that the oil content of the fish in winter, i.e. the season of greatest abundance, is far below a profitable level. The small fish found in the inshore waters in the spring are also of very low oil content.

The catches made with the lampara net in South Australia, by the Kangaroo Investigations' vessel "Corwa", have already been referred to (see p. 46, and above in this Appendix). Some of them, at least, were made during March at Coffin Bay. For the waters of Victoria and Tasmania a single specimen was taken in June near Cape Pillar (from the stomach of a barracouta), and some occurrences were reported from Port Phillip in October. Some specimens taken in June at Twofold Bay (in the stomachs of salmon) suggested by their immature gonads and apparently fat condition that they might have been derived from Victorian waters.

2. SOUTHERN HERRING.

Samples were taken in beach seine hauls at Port Hacking (September, October), Taree (April), Nambucca River entrance (May, June), Clarence River entrance (August, September, October, November), Ballina (June), Terranora Creek (just south of Tweed River - June), Caloundra (northern end of Moreton Bay - June), and Tewantin (June). These occurrences go far to substantiate the suggestion made in the text that this fish is to be found in the bays and estuaries at all seasons.

These fish mostly exhibited maturity stages I to III and were somewhat fatter than those taken during the previous summer. The November fish (Clarence River), however, were approaching maturity. The oil content of one of the June samples (Tewantin) was estimated at 3.8 per cent (equivalent to 25.0 per cent of the dry meal, 22.75 per cent of the meal with 10 per cent of water, and estimated to yield 9.25 gallons per ton of fish). Since at other seasons the oil content would probably be, if anything, lower than this figure (since closer to the spawning periods), it seems clear that this species also would be useless for oil reduction.

3. SPRAT.

Shoals of sprats were seen on several occasions, mostly by day, during May and June in the d'Entrecasteaux Channel (between Bruni Island and the mainland of Tasmania). Seven shots were made with the lampara, all by day, but none were successful, only a few fish being taken in one or two of the hauls. These together with others caught in the "ring net" were placed in the bait tank, but most of them died within a day and no trial of tuna fishing could be made. The fish scaled easily and were badly buffeted about in the tank owing to bad weather, and these factors may have been responsible for the high mortality (cf. p. 94). The larger of these fish were mostly at maturity stage VII.

4. SANDY SPRAT.

Samples were taken at Twofold Bay (July, September, November), Merimbula (just north of Eden - September), Greenwell Point (September), Port Hacking (August), Port Jackson (August, September), Port Stephens (October), and Ballina (April to November). The larger of these specimens exhibited all ranges of maturity from II to VII. These occurrences go far to substantiate the suggestion made in the text that this fish is to be found in the inshore waters at all seasons.

5. BLUE SPRAT.

Samples were taken in New South Wales waters, at Twofold Bay (May, September), Merimbula (September), Jervis Bay (September, October), Port Hacking (August, September, October), Port Jackson (July, September), and Port Stephens (October). In Tasmanian waters some were taken at Hummock Island (June), Lady Barron (south end of Flinders Island - July), and Long Island (July), while for Western Australia specimens were obtained from Fremantle in May and June. These occurrences support the suggestion made in the text that this fish is to be found in the inshore waters at all seasons.

6. MARAY.

A few specimens were taken from Jervis Bay (November), Port Hacking (August), Port Jackson (April), Broken Bay (August) and Port Stephens (April).

7. ANCHOVY.

In New South Wales waters samples were taken from Twofold Bay (November), Merimbula (September), Bateman's

Bay (September, October), Beecroft Head (just north of Jervis Bay - November), Lake Illawarra (just south of Wollongong - September), Port Jackson (July to September) and Ballina (April to July). For Victoria and Tasmania anchovies were noted in the Flinders Island region (May and July), Oyster Bay (just north of Maria Island - June), and Port Phillip (September). The "ring net" was used to fill the bait tank with fish from Oyster Bay, and some slight success was had with these for bluefin tuna fishing off St.Helen's, although the tuna were not particularly numerous. In South Australia a few fish were found at Coffin Bay in March, and in Western Australia specimens were got from the South Coast (February), and from Red Bluff, sixty miles north of Carnarvon (i.e. approximately on the Tropic) in the stomach of a tuna, *Kishinoella* sp. (June); this last record becomes now the most northerly one for this species on the western coast of Australia (cf. p.).

Samples from Port Jackson (July) and Oyster Bay (June) were analysed for oil content. The former fish, which were approaching sexual maturity (stages III to V) contained 1.26 per cent of oil (equivalent to 5.1 per cent of the dry meal, 4.6 per cent of the meal with 10 per cent water, and estimated to yield 3.1 gallons per ton of fish); the latter, which were immature (stages I to II) and slightly smaller, contained 3.02 per cent (equivalent to 12.65 per cent of the dry meal, 11.37 per cent of meal with 10 per cent of water, and estimated to yield 7.35 gallons per ton of fish). These results rather confirm the conclusion suggested by the earlier ones (see p. and Table II), that at no season does the anchovy have a high enough oil content for commercial reduction purposes.

8. "SCALY MACKEREL"

A sample of this fish was obtained from Fremantle, in June.

Table 1 - Showing incidence of pilchard eggs and larvae, and anchovy and maray larvae, in stramin-net plankton hauls made by the Warreen.

Date 1938	Station No.	Approximate Position		Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
26:5	12/38	Friar Rocks	D.	100	100-0	20	1/1	-	-	-
28:5	14/38	" "	S.	100	100-0	20	1/1	-	-	-
1:6	15/38	Maria Isl.	D.	100	100-0	20	1/1	-	-	-
2:6	18/38	" "	D.	100	100-0	20	1/1	-	-	-
"	"	" "	D.	200	100-0	20	1/1	-	-	-
29:7	22/38	Babel Isl.	D.	100	100-0	20	1/1	-	-	-
14:8	25/38	Twofold Bay	D.	100	100-0	20	1/1	-	-	-
"	"	" "	D.	200	100-0	20	1/1	-	-	-
2:9	30/38	Port Hacking	S.	100	25	30	1/2	-	-	-
"	"	" "	S.	200	50	30	1/1	0+24	-	1
"	31/38	Broken Bay	S.	100	25	30	1/1	-	-	-
"	"	" "	S.	200	50	40	1/1	0+12	-	-
"	31a/38	" "	S.	100	0	60	1/5	-	-	-
"	"	" "	S.	200	15	60	1/1	0+ 6	-	-
"	31b/38	" "	S.	200	0	80	1/1	-	-	-
3:9	33/38	Norah Head	S.	100	10	60	1/9	-	-	-
"	"	" "	S.	200	15	60	2/3	-	-	-
4:9	34/38	Pt. Stephens	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	20	30	1/1	42+ 5	-	-
5:9	35/38	C. Hawke	S.	100	12	30	1/1	-	-	1
"	"	" "	S.	200	25	30	1/1	-	-	-
"	36/38	Camden Haven	S.	200	0	30	1/1	0+ 8	-	-
"	37/38	Smoky Cape	S.	100	15	30	1/1	1+ 8	-	-
"	"	" "	S.	200	15	30	1/1	44+75	-	-
6:9	37a/38	Coff's Harbour	S.	100*	20	60	1/1	19+51	-	-
"	38/38	Richmond River	S.	100	0	15	1/1	-	-	-
7:9	39/38	Pt. Danger	S.	100	15	30	1/1	0+47	6	34
12:9	40/38	C. Moreton	S.	100	25	60	1/1	0+47	1	4
13:9	41/38	Double Isl. Pt.	S.	100	25	30	1/1	7+33	-	-
"	42/38	Sandy Cape	S.	100	20	30	1/1	-	-	-
"	"	" "	S.	200	0	30	1/1	-	-	-
14:9	43/38	Hervey Bay	S.	100	15	30	1/1	-	3	-
"	"	" "	S.	200	0	30	1/1	-	2	-
"	44/38	Bustard Bay	S.	100	0	30	3/4	-	-	-

* Net torn during haul and part of collection probably lost.

Table 1 - Cont'd.

Date 1938	Station No.	Approximate Position		Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
14:9	44/38	Bustard Bay	S.	200	15	30	1/4	-	11	-
17:9	45/38	Capricorn Isl.	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	25	30	1/1	-	-	-
19:9	46/38	Sandy Cape	S.	100	0	30	1/1	-	12	17
"	"	" "	S.	200	25	30	1/1	1+6	34	224
20:9	47/38	" "	D.	100	0	30	1/1	-	-	1
"	"	" "	D.	200	100	30	1/1	-	-	5
"	41a/38	Double Isl. Pt.	S.	100	0	30	1/1	1+0	-	-
"	"	" "	S.	200	25	30	1/1	57+1	-	1
"	40a/38	C. Moreton	S.	100	0	30	1/1	0+57	5	2
"	"	" "	S.	200	25	30	1/1	1+212	17	35
21:9	48/38	" "	D.	100	50	30	1/1	0+3	1	-
"	49/38	C. Byron	S.	100	0	30	1/1	18+9	1	1
"	"	"	S.	200	25	30	1/1	176+47	?4	4
22:9	50/38	"	D.	100	0	30	7/8	-	-	-
"	"	"	D.	200	100	30	1/1	0+?2	?3	-
23:9	51/38	Coff's Harbour	S.	100	0	30	1/1	1250+5	-	-
"	"	" "	S.	200	25	30	1/1	3750+?1	?1	-
"	52/38	" "	D.	100	0	30	1/1	0+1	-	-
"	"	" "	D.	200	100	30	1/2	15+1	-	-
26:9	53/38	Smoky Cape	S.	100	0	30	1/1	0+1	-	-
"	"	" "	S.	200	25	30	1/1	0+48	-	-
"	54/38	" "	D.	100	0	30	1/2	-	-	-
"	"	" "	D.	200	100	30	1/1	-	-	-
27:9	55/38	Pt. Stephens	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	25	30	1/1	-	-	-
"	56/38	" "	D.	100	0	30	1/1	-	-	-
"	"	" "	D.	200	100	30	1/1	-	-	-
28:9	33a/38	Norah Head	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	25	30	1/1	-	-	-
29:9	57/38	Pt. Hacking	D.	100	0	15	1/1	0+1	-	-
"	"	" "	D.	200	100	15	1/1	-	-	-
"	30a/38	" "	S.	100	0	30	1/1	0+1	-	-
"	"	" "	S.	200	25	30	1/1	0+3	?2	-
11:10	58/38	Jervis Bay	S.	100	0	30	1/1	-	-	-

Table 1 - Cont'd.

Date 1938	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
11:10	58/38	Jervis Bay S.	200	25	30	1/1	0+3	-	-
"	59/38	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
12:10	60/38	Montague Isl. D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
"	61/38	" " S.	100	0	30	1/9	-	-	-
"	"	" " S.	200	25	30	2/21	-	-	-
"	28a/38	Twofold Bay S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
13:10	25a/38	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
16:10	23a/38	Babel Isl. S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	20	30	1/1	-	-	-
"	22a/38	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
"	62/38	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
17:10	6a/38	St. Helens. D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
"	3a/38	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	20	30	1/10	-	-	-
18:10	17a/38	Maria Isl. S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/5	-	-	-
21:10	13a/38	Friar Rocks S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/5	-	-	-
"	63/38	C. Pillar D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
24:10	18a/38	Maria Isl. D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
2:11	50b/38	Pt. Hacking S.	100	0	30	2/3	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
"	57a/38	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
10:11	64/38	" " S.	100	0	30	1/1	0+1	2	-
"	"	" " S.	200	25	30	1/1	0+6	3	-
11:11	65/38	" " D.	100	0	30	1/1	-	-	-

Table 1 - Cont'd.

Date 1938	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
11:11	65/38	Port Hacking	D.	200	100	30	1/1	-	-	-
12:11	66/38	Jervis Bay	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	25	30	1/4	-	-	-
13:11	67/38	" "	D.	100	0	30	1/3	-	-	-
"	"	" "	D.	200	100	30	1/3	-	-	-
16:11	68/38	Montague Isl.	S.	100	0	30	1/6	-	-	-
"	"	" "	S.	200	25	30	1/40	-	-	-
18:11	69/38	" "	D.	100	0	30	1/2	-	-	-
"	"	" "	D.	200	100	30	1/4	-	-	-
25:11	73/38	Babel Isl.	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	25	30	1/1	-	-	-
"	74/38	" "	D.	100	0	30	1/1	-	-	-
"	"	" "	D.	200	100	30	1/2	-	-	-
28:11	76/38	Twofold Bay	D.	100	0	30	1/1	-	-	-
"	"	" "	D.	200	100	30	1/2	-	-	-
29:11	77/38	" "	S.	100	0	30	1/2	-	-	-
"	"	" "	S.	200	25	30	1/1	-	-	-
5:12	84/38	Montague Isl.	S.	100	0	30	1/1	-	-	-
12:12	96/38	" "	D.	100	0	30	1/1	-	-	-
"	"	" "	D.	200	100	30	1/1	-	-	-
"	97/38	" "	S.	100	0	30	1/2	-	35	-
"	"	" "	S.	200	25	30	1/7	-	25	-
13:12	100/38	Jervis Bay	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	25	30	1/1	-	-	-
14:12	102/38	" "	D.	100	0	30	1/1	-	-	-
"	"	" "	D.	200	100	30	1/1	-	-	-
"	103/38	Pt. Hacking	S.	100	0	30	1/1	-	7	-
"	"	" "	S.	200	25	30	1/1	0+10	85	-
15:12	104/38	" "	D.	100	0	30	1/1	-	9	-
"	"	" "	D.	200	100	30	1/1	-	3	-
17:12	105/38	Broken Bay	S.	100	0	30	1/1	-	-	-
"	"	" "	S.	200	25	30	1/1	-	1	-
"	106/38	" "	D.	100	0	30	1/1	-	-	-
"	"	" "	D.	200	100	30	1/1	-	6	-
"	107/38	Pt. Stephens	S.	100	0	30	1/1	-	1	-
"	"	" "	S.	200	25	30	1/1	1+0	24	-

Table 1 - Cont'd.

Date 1938	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
19:12	108/38	Pt. Stephens D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
1939 5:1	1/39	Pt. Hacking D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
"	2/39	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	0+2	-	-
6:1	5/39	Jervis Bay D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
7:1	6/39	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	0+2	-	-
8:1	10/39	C. Howe S.	100	0	30	1/1	-	5	-
11:1	19/39	Maria Isl. S.	100	0	30	1/1	-	-	-
19:1	24/39	C. Pillar S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	100	30	1/1	-	-	-
20:1	26/39	St. Helen's S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
"	29/39	Babel Island S.	100	0	30	1/1	-	2	-
"	"	" " S.	200	25	30	1/1	-	113	-
21:1	31/39	Kent Isl. S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
23:1	36/39	Twofold Bay D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
24:1	37/39	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
25:1	40/39	Jervis Bay S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
"	41/39	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
"	43/49	Pt. Hacking D.	100	0	30	1/1	0+11	8	-
"	"	" " D.	200	100	30	1/1	0+5	6	1
26:1	44/39	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	0+8	1	-
4:2	45/39	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
"	46/39	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-

Table 1 - Cont'd.

Date 1939	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
7:2	48/39	Jervis Bay S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	--	-
8:2	51/39	Twofold Bay S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/10	-	-	-
13:2	61/39	Port Fairy S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
18:2	69/39	St. Vincent's Gf. S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	15	30	1/1	-	-	-
"	71/39	Investigator Str. S.	100	0	30	1/1	0+257	16	8
"	"	" " S.	200	25	30	1/1	4+713	20	26
20:2	76/39	Spencer's Gulf S.	100	10	30	1/1	-	-	-
22:2	83/39	Investigator Str. S.	100	0	30	1/24	-	-	-
"	"	" " S.	200	25	30	1/12	0+1	-	-
2:3	92/39	C. Jervis S.	100	0	30	1/1	0+4	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
5:3	98/39	Lacepede Bay S.	100	0	30	1/1	3+35	77	-
"	"	" " S.	200	25	30	1/1	5+45	13	-
9:4	100/39	King Island S.	100	0	30	1/1	-	1	-
"	"	" " S.	200	25	30	1/1	-	-	-
"	103/39	Central Bass Str. S.	100	0	30	1/1	-	-	-
"	"	" " " S.	200	25	30	1/1	0+1	1	-
10:4	105/39	St. Helen's S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
"	106/39	" " D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
11:4	107/39	Maria Isl. D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
"	108/39	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	25	30	1/1	-	-	-
17:4	118/39	Twofold Bay D.	100	0	30	1/1	-	-	-
"	"	" " D.	200	100	30	1/1	-	-	-
"	119/39	" " S.	100	0	30	1/1	-	-	-
"	"	" " S.	200	50	30	1/1	-	-	-
18:4	120/39	Montague Isl. S.	100	0	30	1/1	0+34	1	-
"	"	" " S.	200	50	30	1/1	10+54	1	-
1:5	124/39	Pt. Hacking D.	100	100	30	1/1	Collection lost		

Table 1 - Cont'd.

Date 1939	Station No.	Approximate Position		Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
2:5	125/39	Pt. Hacking	S.	100	25	30	1/1	0+1	1	-
"	125a/39	Pt. Jackson	S.	100	0	30	1/1	0+1	-	-
"	"	" "	S.	100	25	30	1/1	-	-	-
3:5	126/39	Norah Head	S.	100	0	60	1/1	43+9	-	-
"	"	" "	S.	100	25	60	1/1	7+3	-	-
"	127/39	" "	D.	100	0	60	1/1	-	-	-
"	"	" "	D.	100	100	60	1/1	-	-	-
"	128/39	Pt. Stephens	S.	100	25	60	1/1	0+8	-	-
"	129/39	" "	D.	100	100	60	1/1	0+5	-	-
5:5	131/39	Coff's Harbour	S.	100	0	60	1/1	-	-	-
"	"	" "	S.	100	25	60	1/1	-	-	-
"	132/39	" "	D.	100	0	60	1/1	-	-	-
"	"	" "	D.	100	100	60	1/1	-	-	-
6:5	133/39	C. Byron	S.	100	0	60	1/1	-	-	-
"	"	" "	S.	100	25	60	1/1	-	-	-
"	134/39	" "	D.	100	0	60	1/1	-	-	-
"	"	" "	D.	100	100	60	1/1	-	-	-
8:5	134a/39	Bustard Bay	S.	100	30	30	1/1	-	-	-
14:5	135/39	C. Moreton	D.	100	0	60	1/1	-	-	-
"	"	" "	D.	100	100	60	1/1	-	-	-
"	136/39	" "	S.	100	0	60	1/1	-	4	1
"	"	" "	S.	100	25	60	1/1	-	73	3
16:5	137/39	Smoky Cape	S.	100	0	60	1/1	-	-	-
"	"	" "	S.	100	25	60	1/1	-	-	-
"	138/39	" "	D.	100	0	60	1/1	-	-	-
"	"	" "	D.	100	100	60	1/1	-	-	-
17:5	139/39	Crowdy Hd.	S.	100	0	60	1/1	-	-	-
"	"	" "	S.	100	25	60	1/1	-	1	-
"	139a/39	Pt. Stephens	S.	100	0	30	1/1	0+1	-	-
"	"	" "	S.	100	25	30	1/1	-	-	-
29:5	140/39	Pt. Hacking	D.	100	0	60	4/5	-	-	-
"	"	" "	D.	100	100	60	4/5	-	-	-
30:5	141/39	" "	S.	100	0	60	4/5	8+53	-	-
"	"	" "	S.	100	25	60	4/5	8+2	-	-
"	142/39	Jervis Bay	D.	100	0	30	4/5	0+1	-	-
"	"	" "	D.	200	100	30	1/1	-	-	-

Table 1 - Cont'd.

Date 1939	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
31:5	143/39	Jervis Bay	S. 100	0	30	4/5	4+11	-	-
"	"	" "	S. 200	25	30	4/5	0+37	-	-
"	144/39	Montague Isl.	D. 100	0	30	4/5	-	-	-
"	"	" "	D. 200	100	30	1/1	0+10	-	-
"	145/39	" "	S. 100	0	30	1/1	-	-	-
"	"	" "	S. 200	25	30	1/1	-	-	-
11:6	183/39	C. Pillar	D. 100	0	30	1/1	-	-	-
"	"	" "	D. 200	100	30	1/1	-	-	-
"	184/39	Maria Isl.	S. 100	0	30	1/1	-	-	-
"	"	" "	S. 200	25	30	1/1	-	-	-
"	185/39	" "	D. 100	0	30	1/1	-	-	-
"	"	" "	D. 200	100	30	1/1	-	-	-
12:6	186/39	St. Helen's	S. 100	0	30	1/1	-	-	-
"	"	" "	S. 200	25	30	1/1	-	-	-
"	187/39	" "	D. 100	0	30	1/1	-	-	-
"	"	" "	D. 200	100	30	1/1	-	-	-
13:6	188/39	Babel Isl.	S. 100	0	30	1/1	-	-	-
"	"	" "	S. 200	25	30	1/1	-	2	-
"	189/39	" "	D. 100	0	30	1/1	-	-	-
"	"	" "	D. 200	100	30	1/1	-	-	-
14:6	192/39	Twofold Bay	D. 100	0	30	1/1	-	-	-
"	"	" "	D. 200	100	30	1/1	-	-	-
"	193/39	" "	S. 100	0	30	1/1	-	-	-
"	"	" "	S. 200	25	30	1/1	-	-	-
6:7	194/39	C. Moreton	S. 100	0	15	4/5	-	-	-
"	"	" "	S. 100	50-0	10	4/5	0+6	4	-
"	"	" "	S. 200	0	15	4/5	0+4	3	-
7:7	195/39	Sandy Cape	D. 100	200-0	40	4/5	-	-	-
"	"	" "	D. 200	0	15	4/5	-	-	-
"	196/39	" "	S. 100	0	15	4/5	-	-	2
"	"	" "	S. 100	50-0	10	4/5	-	2	9
"	"	" "	S. 200	0	15	4/5	-	2	15
15:7	197/39	C. Moreton	D. 100	200-0	40	4/5	-	-	-
"	"	" "	D. 200	0	15	4/5	0+4	5	-
16:7	198/39	C. Byron	S. 100	0	15	1/1	511+0	-	-
"	"	" "	S. 100	200-0	40	1/1	211+2	-	-

Table 1 - Cont'd.

Date 1939	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
16:7	198/39	C. Byron S.	200	0	15	4/5	462+0	-	-
"	199/39	" " D.	100	200-0	40	4/5	-	-	-
"	"	" " D.	200	0	15	4/5	-	-	-
"	200/39	Coff's Harbour D.	100	200-0	40	4/5	0+11	1	4
"	"	" " D.	200	0	15	4/5	0+45	4	53
17:7	201/39	" " S.	100	0	15	4/5	0+46	1	1
"	"	" " S.	100	50-0	10	4/5	0+63	2	-
"	"	" " S.	200	0	15	4/5	0+416	8	3
18:7	202/39	Smoky Cape S.	100	0	15	4/5	-	-	-
"	"	" " S.	100	50-0	10	4/5	0+3	-	-
"	"	" " S.	200	0	15	4/5	0+1	-	-
"	203/39	" " D.	100	200-0	40	4/5	0+36	-	2
"	"	" " D.	200	0	15	4/5	0+7	-	-
24:7	204/39	Pt. Stephens S.	100	0	15	4/5	10+0	-	-
"	"	" " S.	100	50-0	10	4/5	-	-	-
"	"	" " S.	200	0	15	4/25	-	-	-
4:8	205/39	Pt. Hacking D.	200	0	15	4/5	0+38	-	1
"	206/39	" " S.	100	50-0	10	4/5	0+5	-	-
"	"	" " S.	200	0	15	4/5	0+3	-	-
23:8	210/39	Jervis Bay S.	100	50-0	10	4/5	-	-	-
"	"	" " S.	200	0	15	4/5	0+2	-	-
25:8	211/39	Twofold Bay S.	100	50-0	10	4/5	-	-	-
"	"	" " S.	200	0	15	4/5	-	-	-
"	212/39	" " D.	100	200-0	40	4/5	-	-	-
"	"	" " D.	200	0	15	4/5	-	-	-
3:9	213/39	Montague Is. S.	100	50-0	10	4/5	-	-	-
"	"	" " S.	200	0	15	2/5	-	-	-
"	214/39	" " D.	100	200-0	40	4/5	-	-	-
"	"	" " D.	200	0	15	4/5	-	-	-
5:9	215/39	Jervis Bay D.	100	200-0	40	4/5	-	-	-
"	"	" " D.	200	0	15	4/5	-	-	-
6:9	216/39	Pt. Hacking S.	100	50-0	10	4/5	-	-	-
"	"	" " S.	200	0	15	4/75	-	-	-
"	217/39	" " D.	100	200-0	40	4/5	-	-	-
"	"	" " D.	200	0	15	4/5	-	-	-
15:9	218/39	C. Byron S.	100	50-0	10	2/15	295+14	2	3

Table 1 - Cont'd.

Date 1939	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
15:9	218/39	C. Byron S.	200	0	15	4/5	245+34	4	-
"	219/39	" " D.	100	200-0	40	4/5	0+1	-	-
"	"	" " D.	200	0	15	4/5	-	-	-
16:9	220/39	Smoky Cape S.	100	50-0	10	4/5	-	-	-
"	"	" " S.	200	0	15	2/25	-	-	-
"	221/39	" " D.	100	200-0	40	4/5	-	-	-
"	"	" " D.	200	0	15	4/5	-	-	-
2:10	222/39	Port Hacking S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	14/25	-	-	-
"	223/39	" " D.	100	200-0	40	7/10	0+15	-	-
"	"	" " D.	200	0	15	7/25	0+5	-	-
4:10	224/39	Jervis Bay D.	100	200-0	40	7/10	-	-	-
"	"	" " D.	200	0	15	7/20	-	-	-
5:10	225/39	" " S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
6:10	226/39	Montague Isl. S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
"	227/39	" " D.	100	200-0	40	7/10	-	-	-
"	"	" " D.	200	0	15	7/10	-	-	-
13:10	239/39	Maria Island S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
14:10	242/39	St. Helen's S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
16:10	244/39	Babel Island S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
17:10	248/39	Twofold Bay S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
24:10	254/39	Port Hacking S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
25:10	255/39	" " D.	100	200-0	40	7/10	-	-	-
"	"	" " D.	200	0	15	7/10	-	-	-
1:11	265/39	Montague Isl. S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
"	266/39	" " D.	100	200-0	40	7/10	-	1	-
"	"	" " D.	200	0	15	7/10	-	-	-
3:11	269/39	Twofold Bay S.	100	50-0	10	1/1	-	3	-

Table 1 - Cont'd.

Date 1939	Station No.	Approximate Position	Net	Depth in Metres	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
3:11	269/39	Twofold Bay S.	200	0	15	7/10	-	-	-
12:11	282/39	Cape Pillar S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
"	283/39	Maria Island S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/20	-	-	-
"	284/39	" " D.	100	200-0	40	7/10	-	-	-
"	"	" " D.	200	0	15	7/10	-	-	-
15:11	299/39	Gippsland Lakes S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
16:11	302/39	Cape Howe D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
22:11	308/39	Port Hacking S.	100	50-0	10	7/10	0+4	1	-
"	"	" " S.	200	0	15	1/10	0+1	1	-
23:11	309/39	" " D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
26:11	313/39	Wilson's Promnty. S.	100	50-0	10	1/1	-	5	-
"	"	" " S.	200	0	15	1/1	1+0	-	-
10:12	331/39	W. Investigator St.S.	100	50-0	10	7/10	-	-	-
"	"	" " S.	200	0	15	7/10	-	-	-
15:12	341/39	St.Vincent's Gf. S.	200	0	15	1/1	77+8	1	-
16:12	342/39	Backstair's Pass. S.	200	0	15	1/1	-	-	-
17:12	343/39	Discovery Bay D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
"	344/39	Port Fairy S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
25:12	345/39	The Paddock D.	100	200-0	40	1/4	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
26:12	346/39	Cape Howe D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/2	-	-	-
"	347/39	Twofold Bay S.	100	50-0	10	1/1	0+3	3	-
"	"	" " S.	200	0	15	1/1	5+0	9	-
27:12	348/39	Montague Island S.	100	50-0	10	1/1	2+1	-	-
"	"	" " S.	200	0	15	1/1	9+0	-	-
"	349/39	" " D.	200	0	15	1/1	-	-	-
28:12	350/39	Jervis Bay S.	100	50-0	10	1/1	32+0	-	-
"	"	" " S.	200	0	15	1/1	190+1	2	-

Table 1 - Cont'd.

Date 1940	Station No.	Approximate Position	Net	Depth in Minutes	Time in Minutes	Fraction Examined	No. Pilchards	No. Anchovy	No. Maray
9:1	1/40	Port Hacking S.	100	50-0	10	1/1	2+2	-	-
"	"	" " S.	200	0	15	1/1	0+1	-	-
"	2/40	" " D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
11:1	3/40	Port Stephens D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
"	4/40	" " S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
13:1	5/40	Smoky Cape S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	1	-
"	6/40	Coff's Harbour S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
14:1	7/40	" " D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
28:1	9/40	Jervis Bay D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
"	10/40	" " S.	100	50-0	10	1/1	2+0	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
29:1	11/40	Montague Isl. S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
30:1	12/40	Twofold Bay S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
16:2	13/40	Maria Island D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/8	-	-	-
18:2	14/40	Cape Pillar S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/3	-	-	-
19:2	15/40	Maria Island S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
21:2	16/40	Babel Island S.	100	50-0	10	1/1	-	-	-
"	"	" " S.	200	0	15	1/1	-	-	-
"	17/40	" " D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
25:2	23/40	Montague Island D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-
27:2	24/40	Port Hacking D.	100	200-0	40	1/1	-	-	-
"	"	" " D.	200	0	15	1/1	-	-	-

Table 2 - Summary of analyses, for water and Oil content, of Australian and New Zealand Clupeoid fishes.

Species	Locality	Date	Approx. Body Length Range (mm.)	Maturity Range	Analysis done by:	% Water	% Oil in Whole Fish	% Oil in Dry Meal	% Oil in Meal with 10 % Water	Estimated Oil Yield (gallons per ton of fish)
Pilchard	Vict.	23/9/37	135-160	I-VII	Jowett and Davies	75.90	1.25	-	4.68	3.04
"	"	27/9/37				78.90	1.08	-	4.60	2.62
"	"	27/1/38				76.50	1.12	-	4.27	2.73
"	N.S.W.	9/8/39	140-180	V-VII	Fisheries	80.89	0.32	1.51	1.37	0.78
"	"	22/1/40	110-170	I-II	"	67.00	14.02	42.50	38.25	34.13
"	N.Z.	-/4/39	130-150	I-II	Shorland	-	8.00	-	-	19.48
"	"	"	170-220			-	8.30	-	-	20.21
"	"	-/6/39	130-150			-	5.89	-	-	13.85
"	"	"	170-220			-	8.07	-	-	19.65
Sandy Sprat	N.S.W.	29/11/38	65-80	II-IV	Fisheries	73.40	1.10	4.13	3.72	2.67
Blue Sprat	"	"	55-70	III-VII	"	72.30	2.73	9.87	8.86	6.65
Anchovy	Vic.	15/9/37	60-100	I-II	Jowett and Davies	75.40	1.22	-	4.45	2.97
"	N.S.W.	3/2/40	75-115	III-V	Fisheries	78.62	0.63	2.95	2.65	1.53

NOTES ON THE ABOVE TABLE.

Approximate Body Length Range and Maturity Range as given represent observed ranges from the samples from which the fish were taken for analysis.

Analysis done by .. Some of the data are taken from Jowett and Davies (1938), some kindly made available by Dr. Shorland and the remainder (Fisheries) were carried out by the Fisheries Division.

Percentage Oil. Jowett and Davies determined directly the % oil in both the whole fish and in the meal dried to moisture content 10%; Shorland's data, as made available to us, give only the former of these two values; in our own analyses generally only the % in the dry meal was directly determined, and the other values calculated from it.

Estimated Oil Yield: This is calculated on the basis: 1 gallon = 9.2 lb. (vide Jowett and Davies, 1938, p.24).

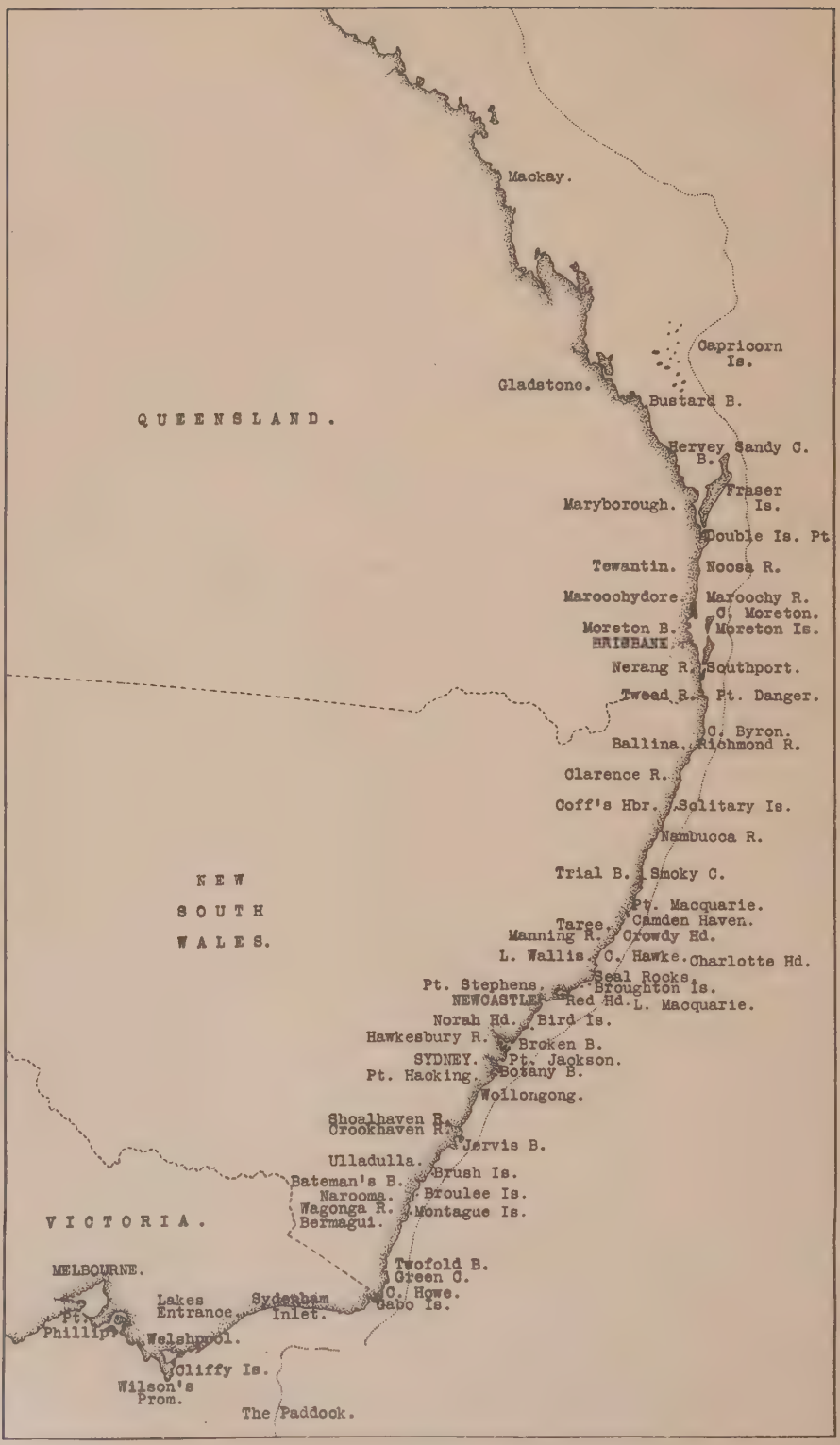

Fig. 1.

Sketch map of Queensland, New South Wales and part of Victoria, showing localities referred to in the text, and in Table 1.

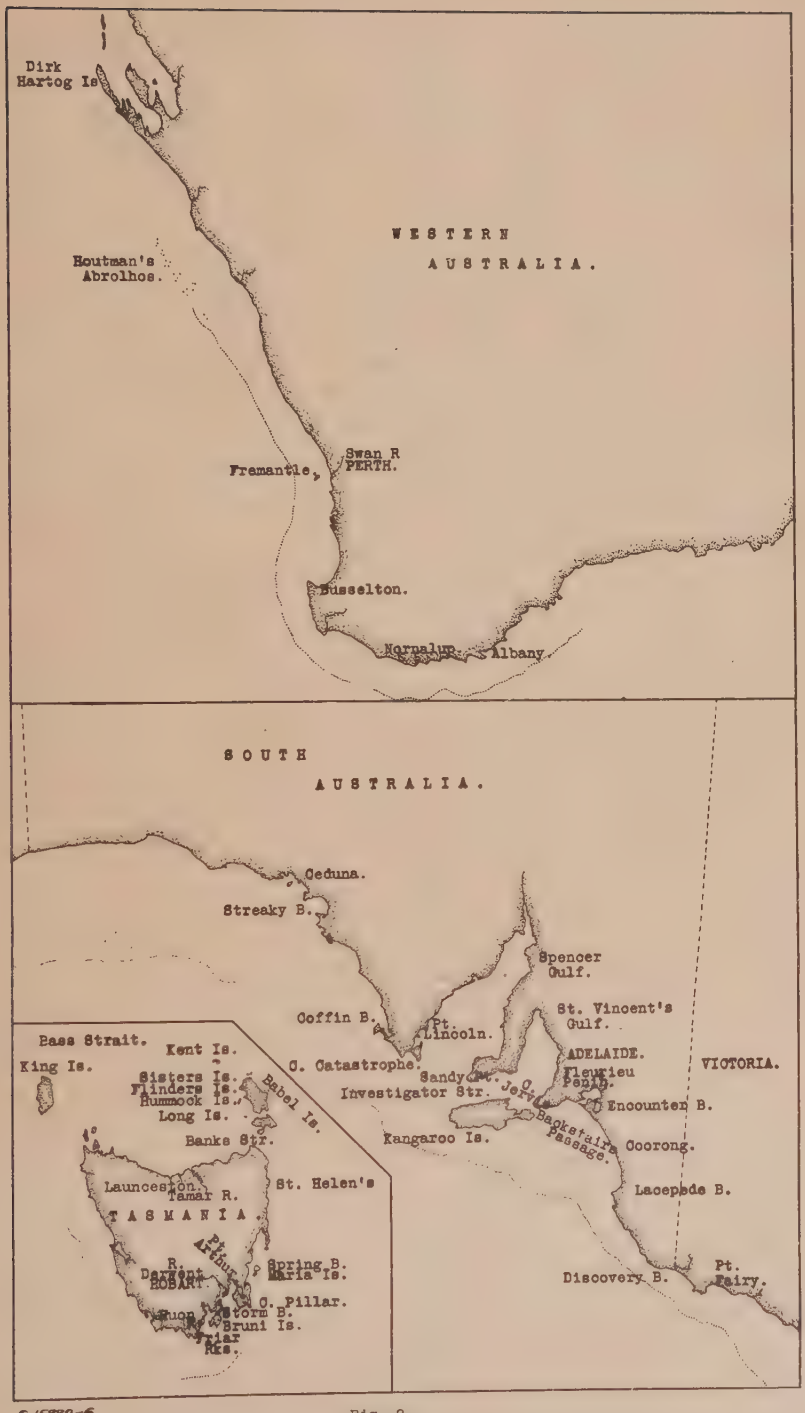

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Fig. 2.

Sketch maps of Western Australia, South Australia and part of Victoria, and Tasmania showing localities referred to in the text, and in Table I.

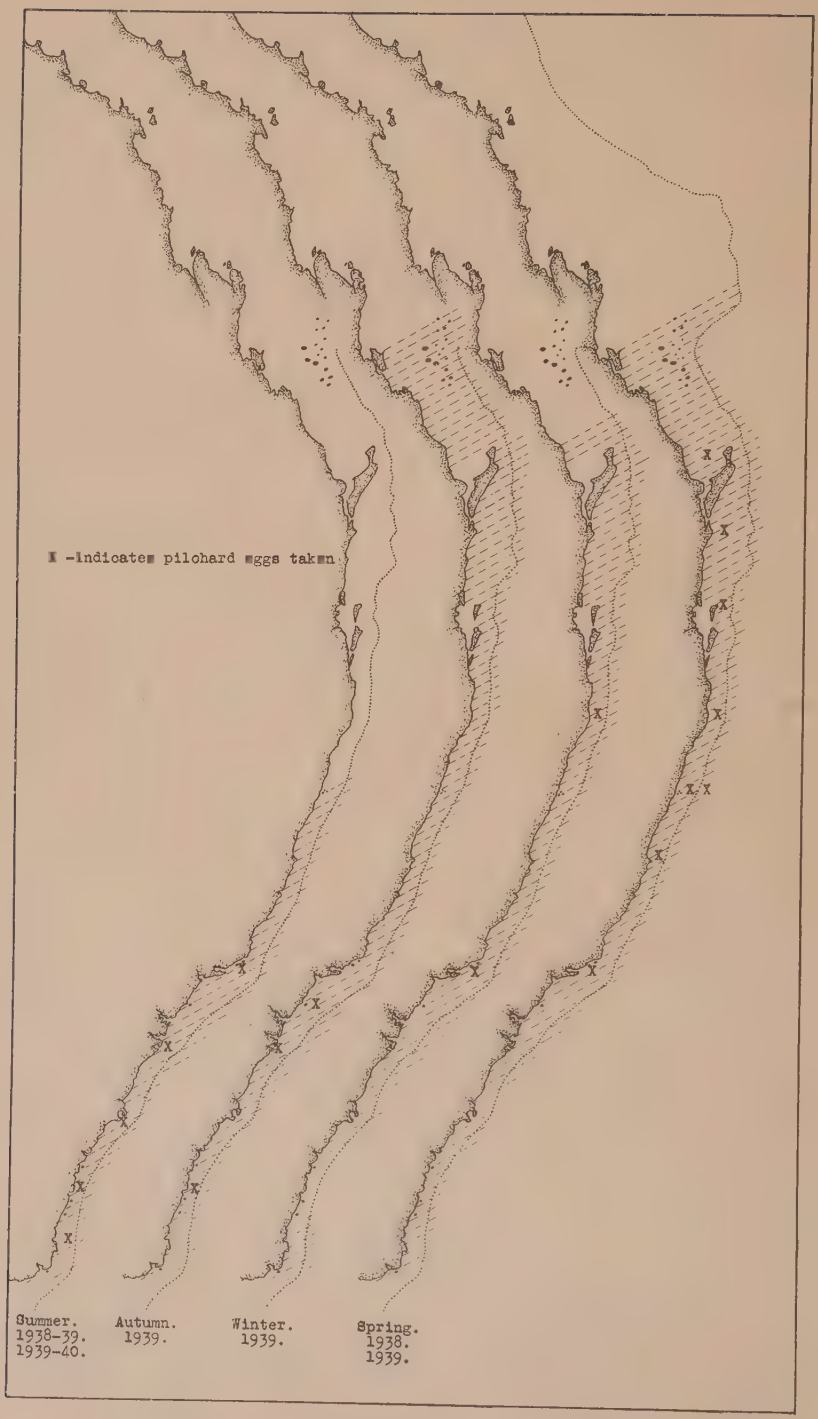


Fig. 3.

Sketch maps showing all localities in which pilchard eggs were taken in oblique or horizontal hauls, at any depth, of stramin plankton nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

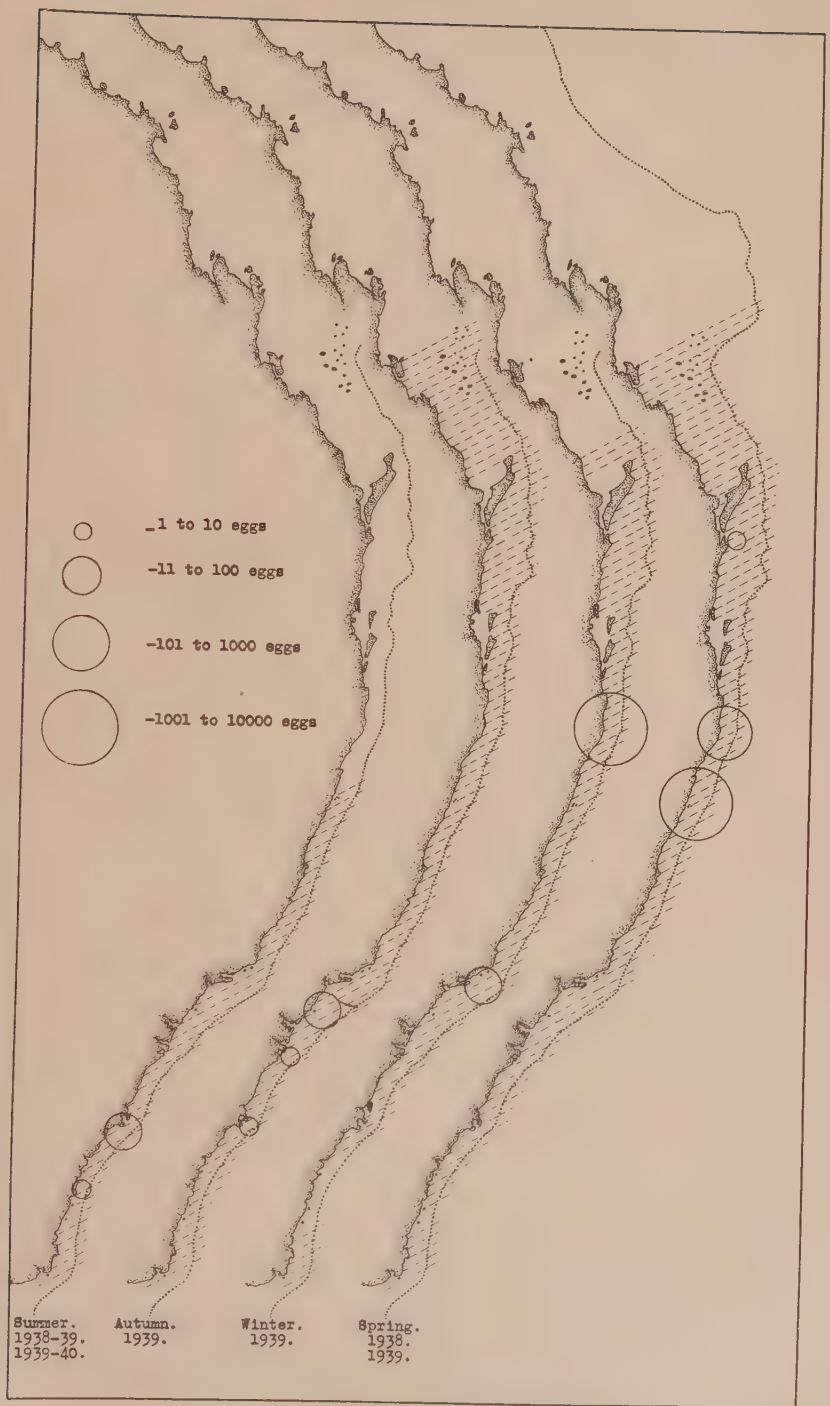


Fig. 4.

Sketch maps showing comparative quantitative distribution of pilchard eggs taken in horizontal hauls, at the surface, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

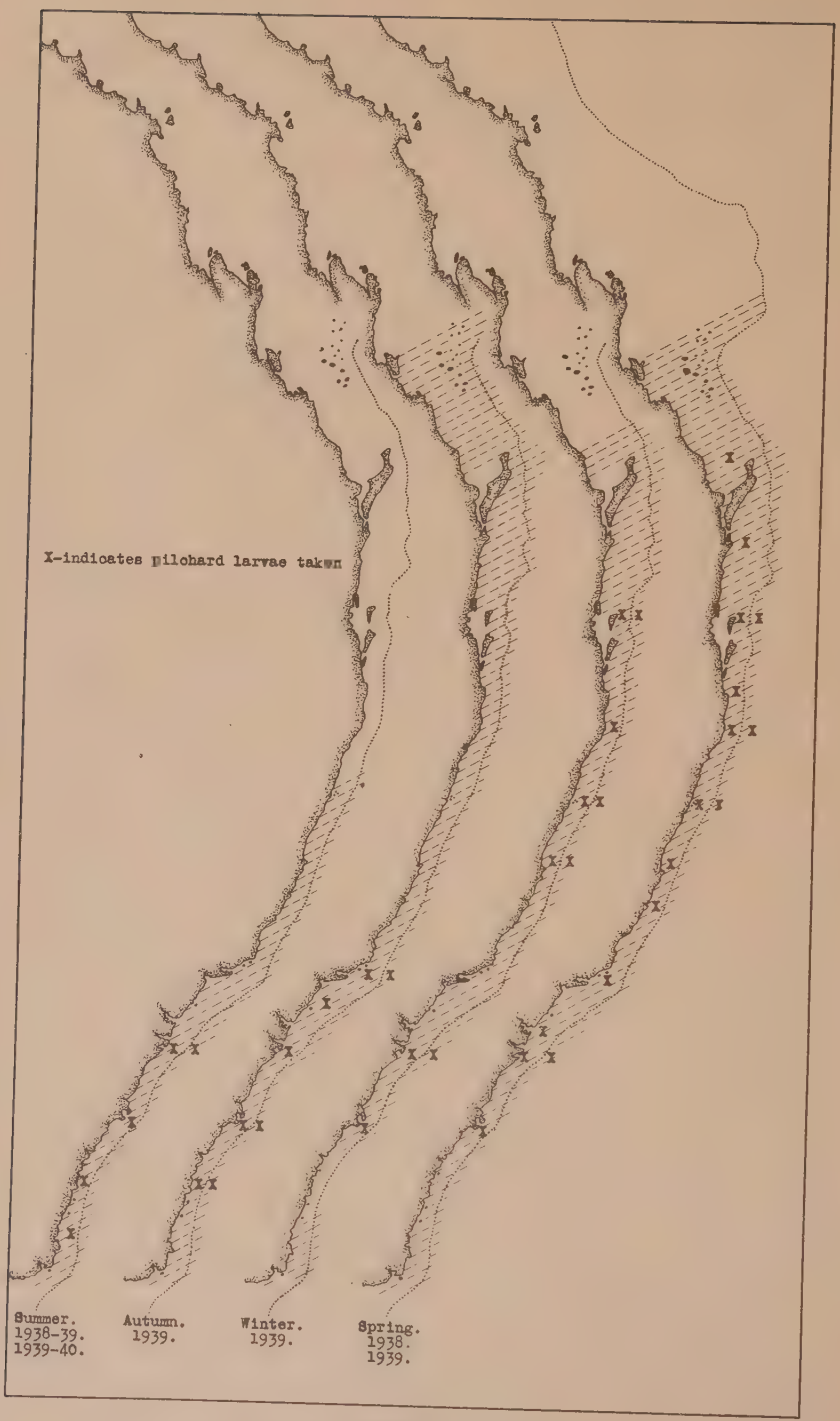


Fig. 5.

Sketch maps showing all localities in which pilchard larvae were taken in oblique or horizontal hauls, at any dept, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

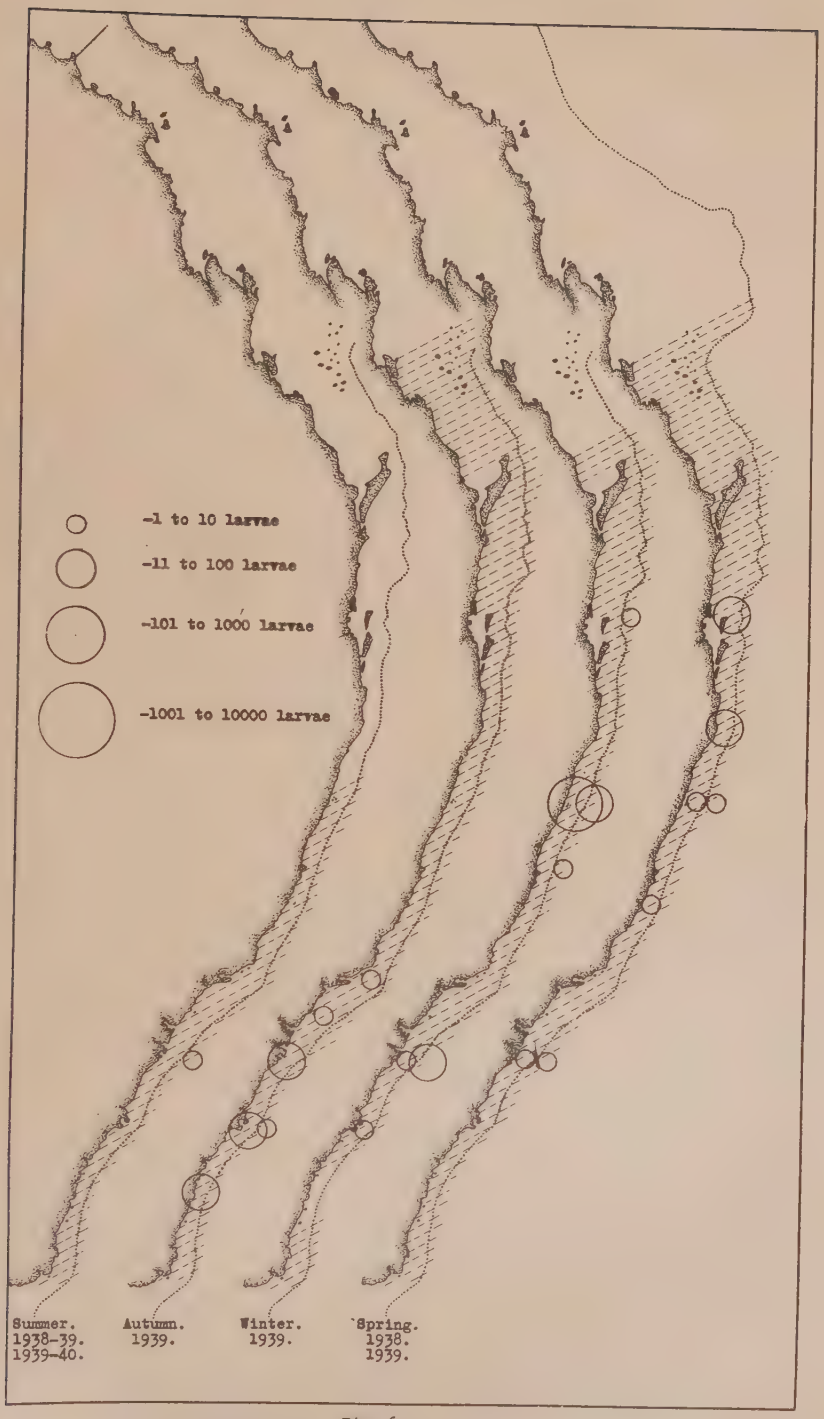


Fig. 6

Sketch maps showing comparative quantative distribution of pilchard larvae taken in horizontal hauls, at the surface, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

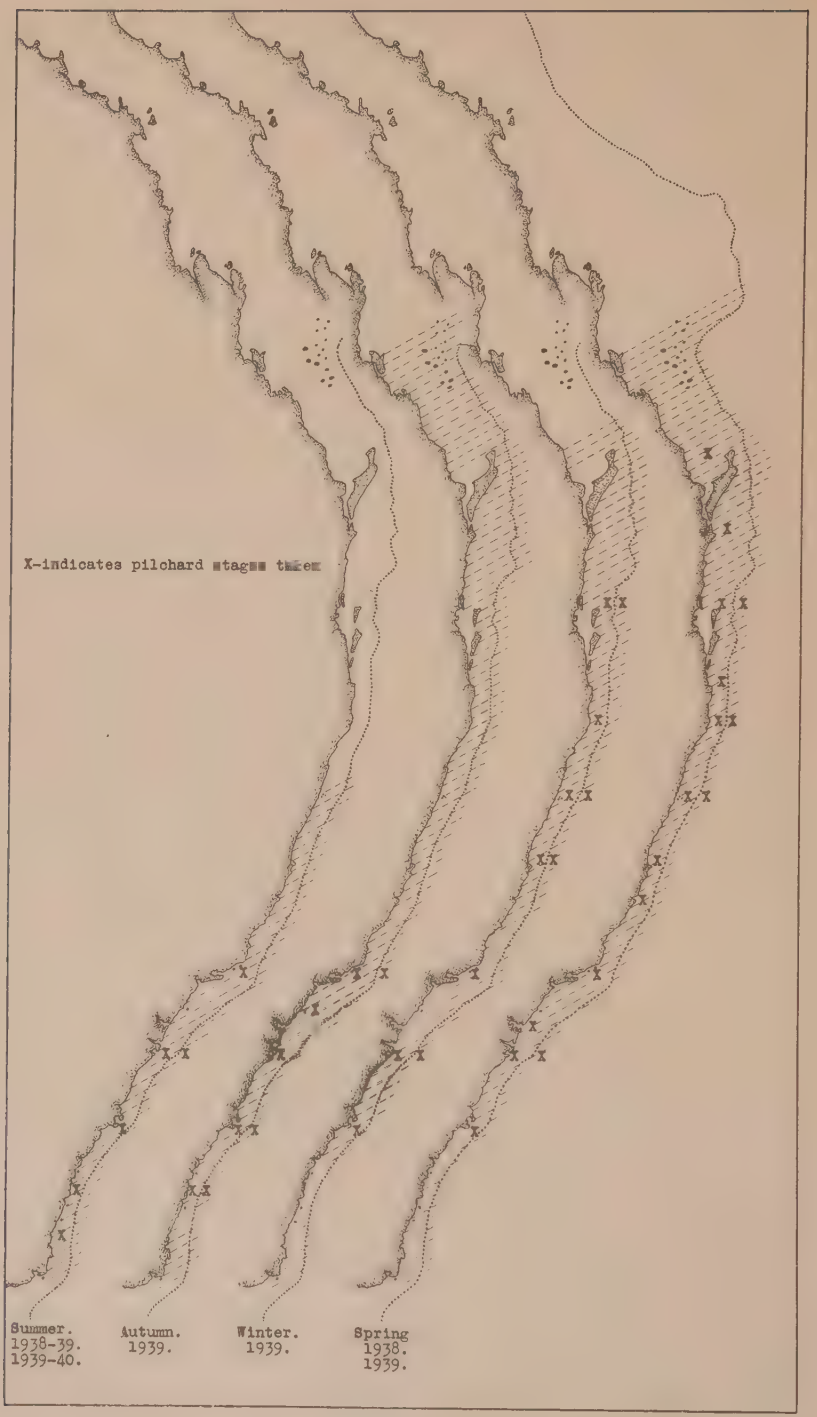


Fig. 7

Sketch maps showing all localities in which pilchard eggs and/or larvae were taken in oblique or horizontal hauls, at any depth, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

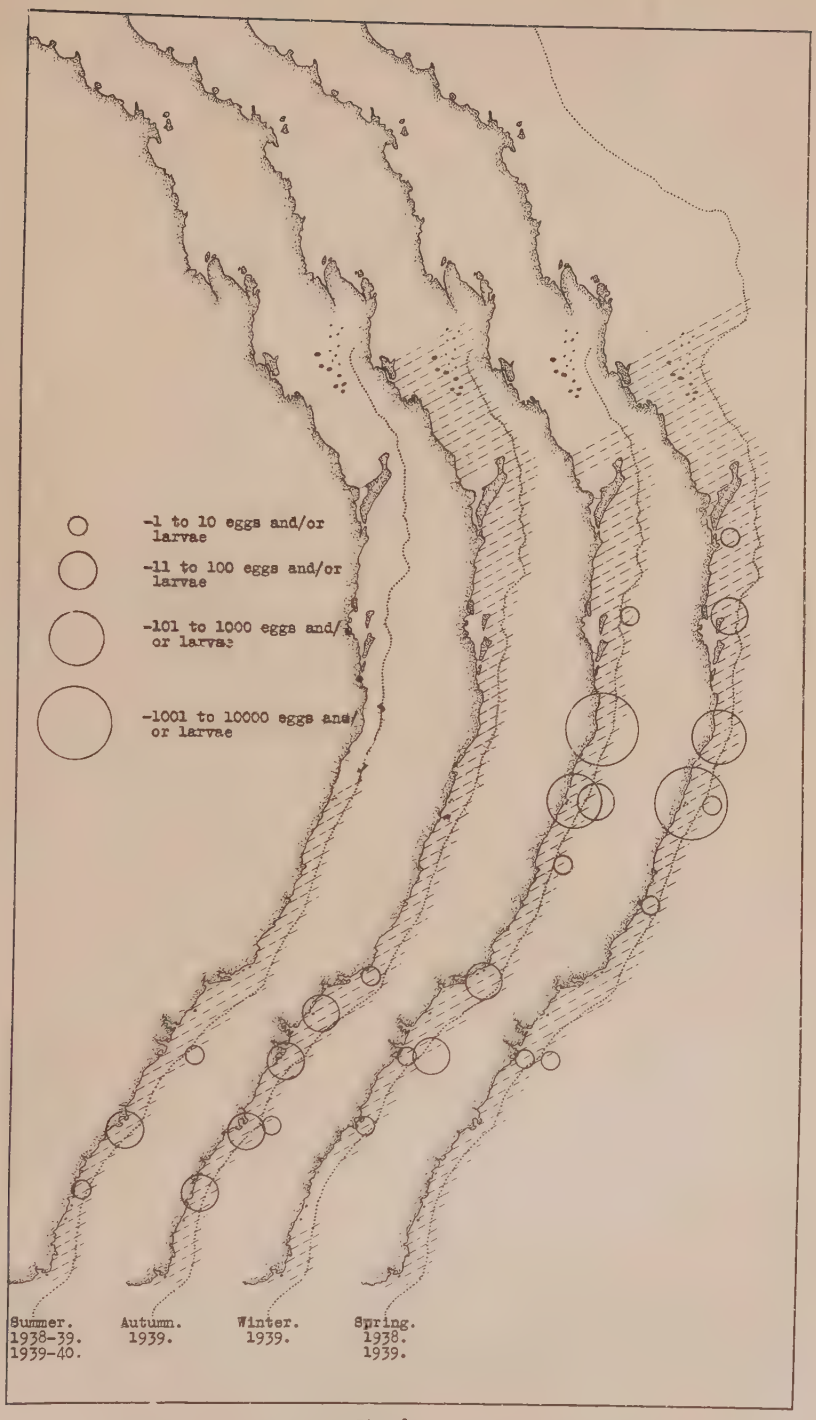

-1 to 10 eggs and/or larvae
-11 to 100 eggs and/or larvae
-101 to 1000 eggs and/or larvae
-1001 to 10000 eggs and/or larvae
Summer. 1938-39. 1939-40.
Autumn. 1939.
Winter. 1939.
Spring. 1938. 1939.

Fig. 8.

Sketch maps showing comparative quantitative distribution of pilchard eggs and/or larvae taken in horizontal hauls at the surface, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

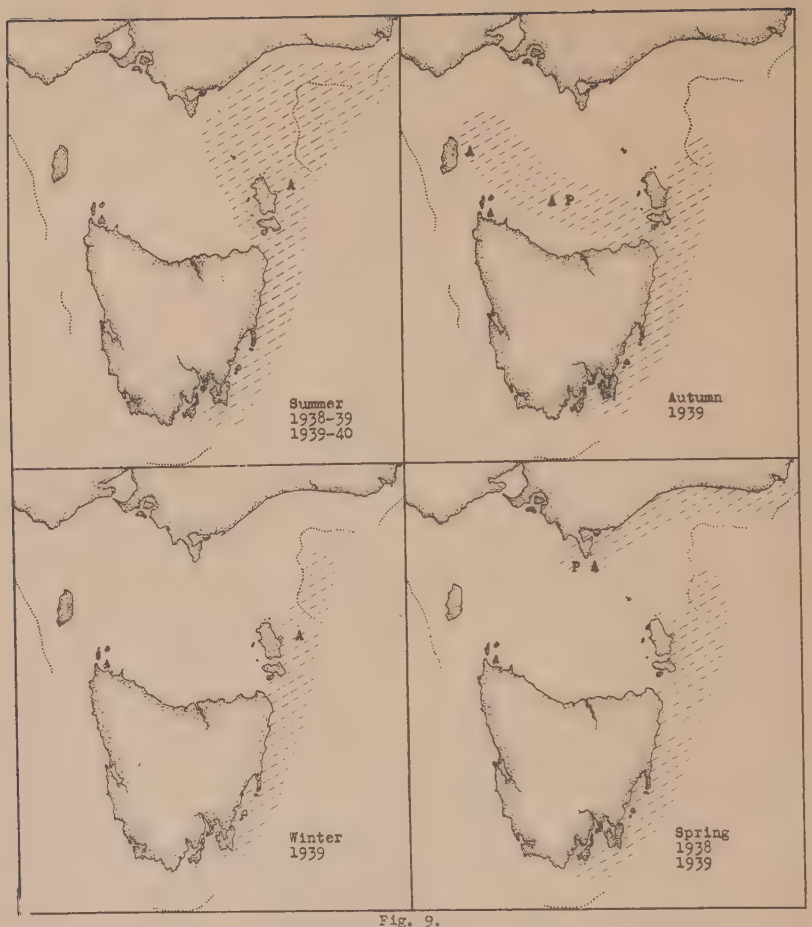


Fig. 9.

Sketch maps showing all localities in which clupeoid eggs and/or larvae (pilchard, anchovy) were taken in oblique or horizontal hauls, at any depth, of stramin plankton-nets in the waters of Victoria and Tasmania during the four seasons. Stippled areas indicate waters in which hauls were made.

P. indicates pilchard stages taken
A. indicates anchovy stages taken

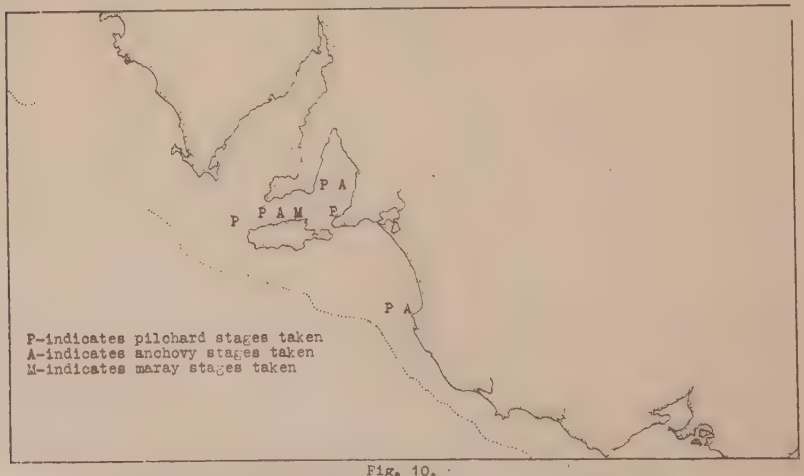
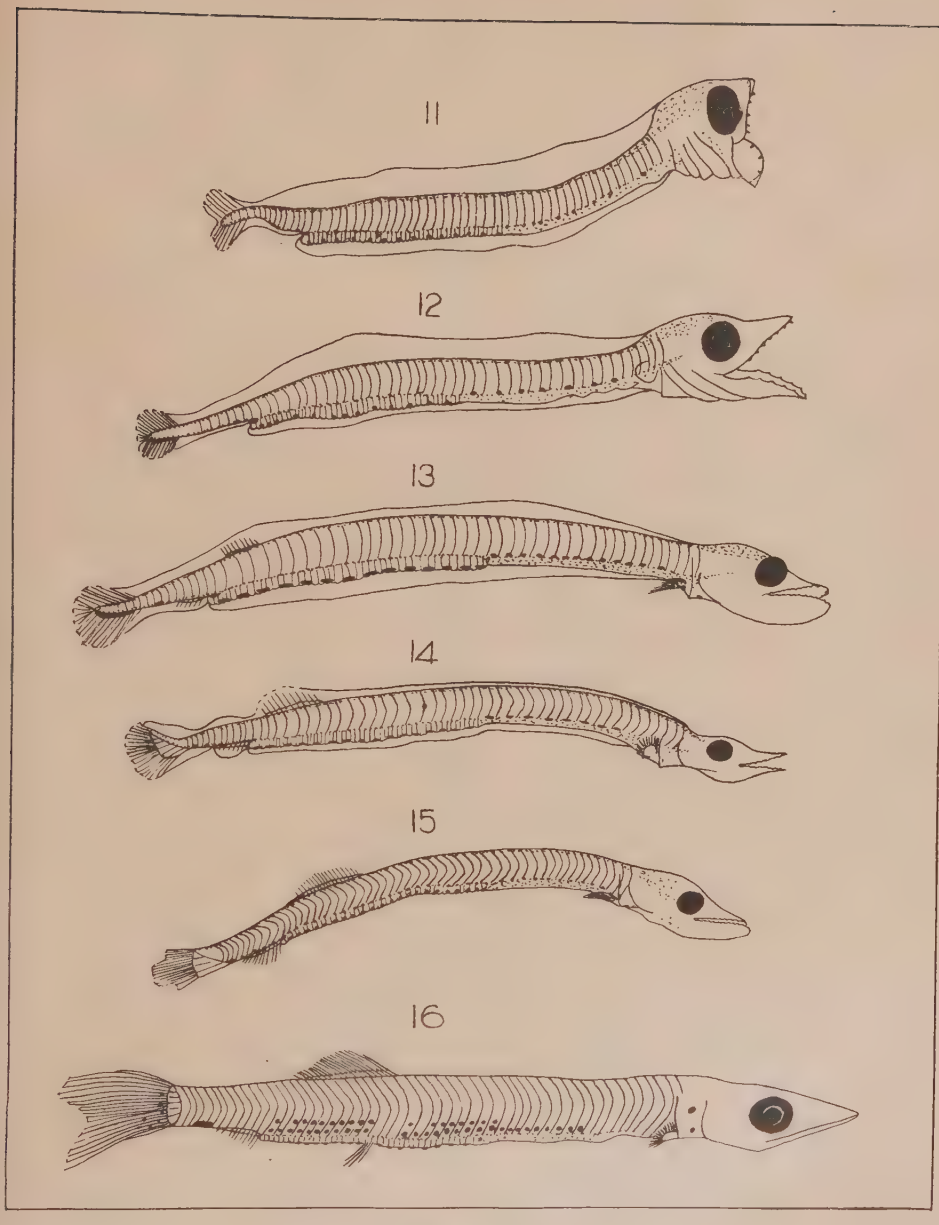


Fig. 10.

Sketch maps showing all localities in which pilchard eggs and/or larvae and other clupeoid larvae (anchovy, maray) were taken in oblique or horizontal hauls, at any depth, of stramin plankton-nets in the waters of South Australia during the months of February, March and December, 1939. Stippled areas indicate waters in which hauls were made.



Figs. 11-16.

Development stages of the marsy larva.

Fig. 11. Larva from Station 46/38, taken in N70. Length 4.4 mm.
Fig. 12. Larva from Station 46/38, taken in N70. Length 6.0 mm.
Fig. 13. Larva from Station 196/39, taken in N100. Length 8.6 mm.
Fig. 14. Larva from Station 46/38, taken in N70. Length 12.9 mm.
Fig. 15. Larva from Station 201/39, taken in N200. Length 18.7 mm.
Fig. 16. Larva from Station 30/38, taken in N200. Length 24.0 mm.

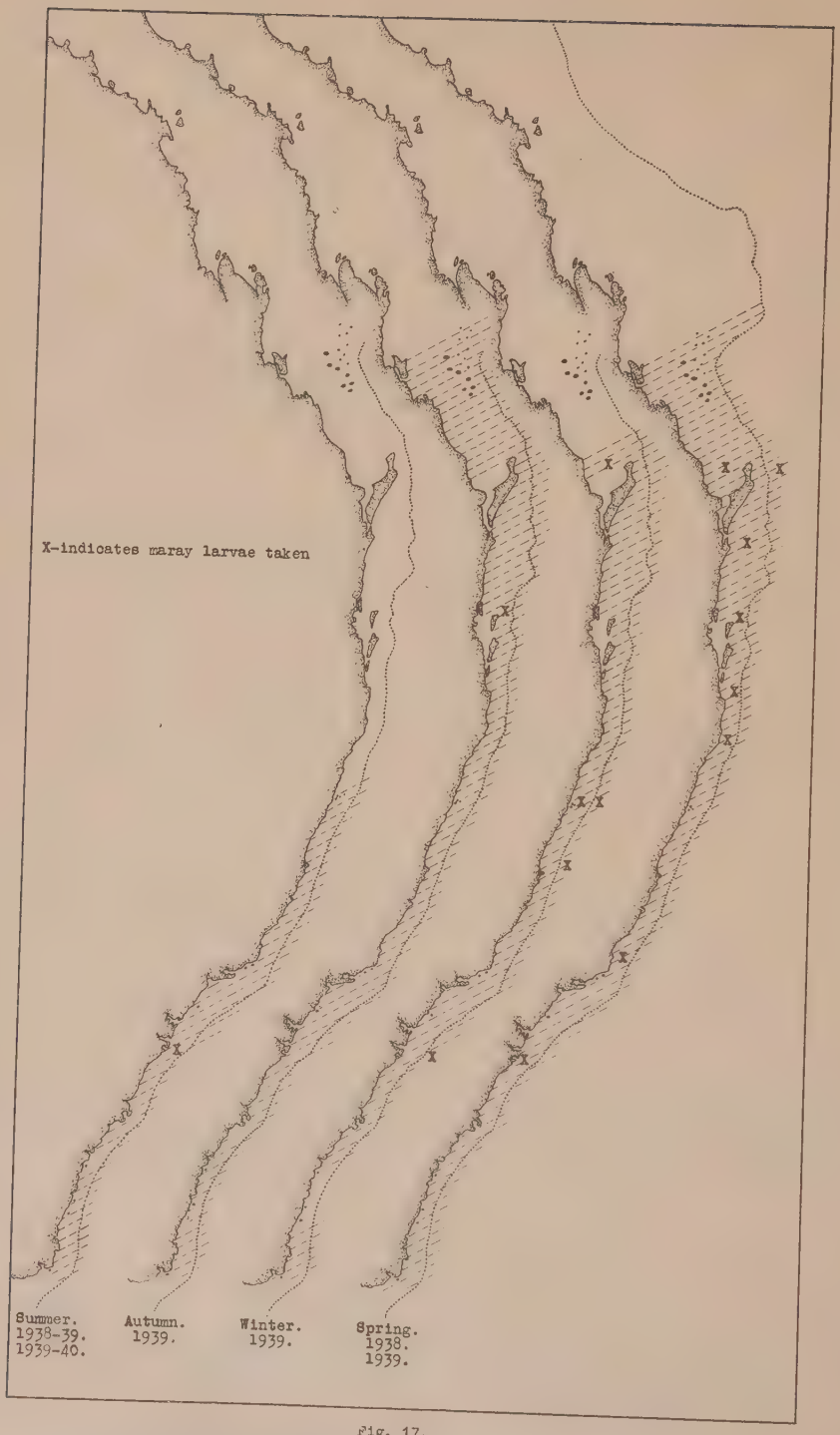


Fig. 17.

Sketch maps showing all localities in which maray larvae were taken in oblique or horizontal hauls, at any depth, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

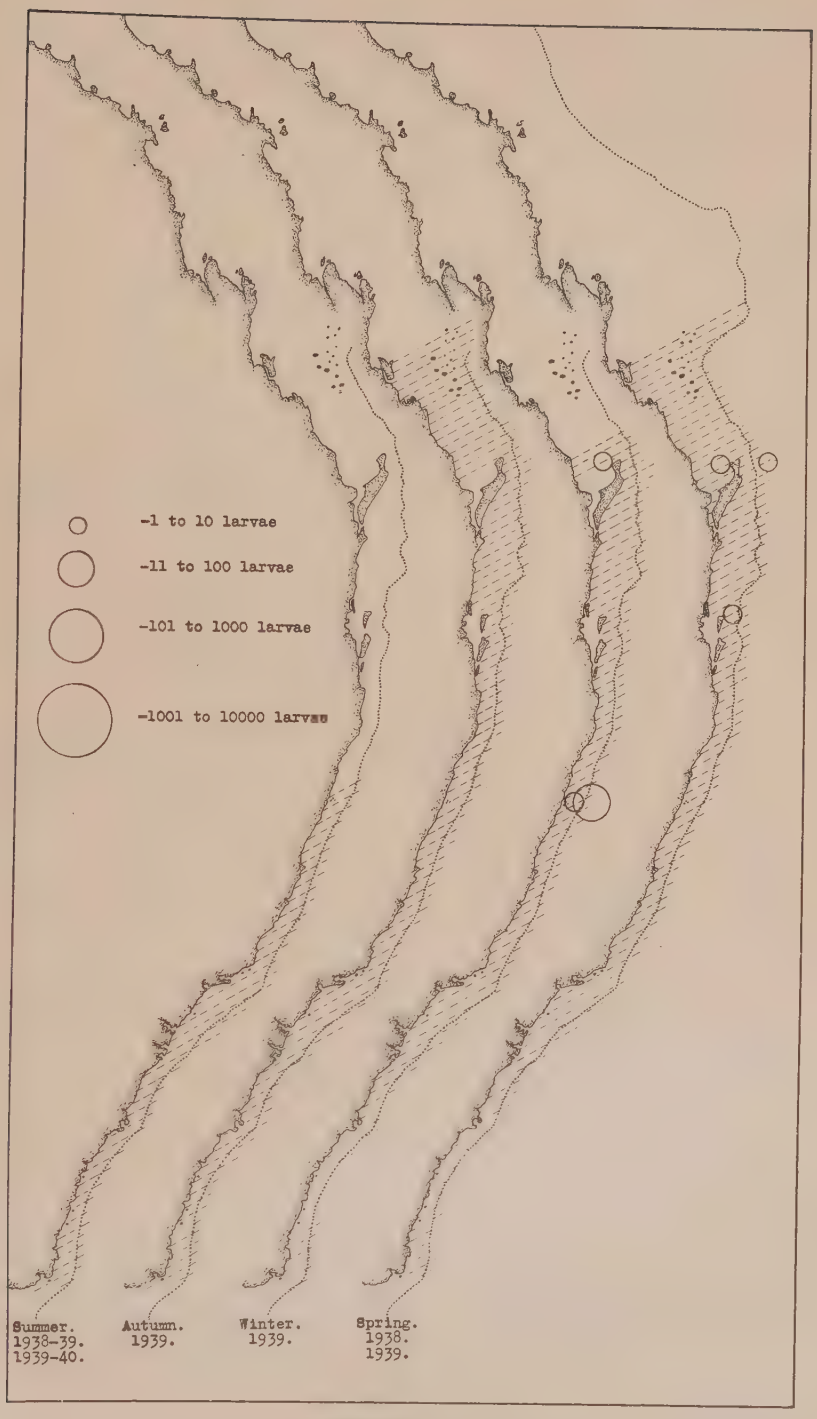
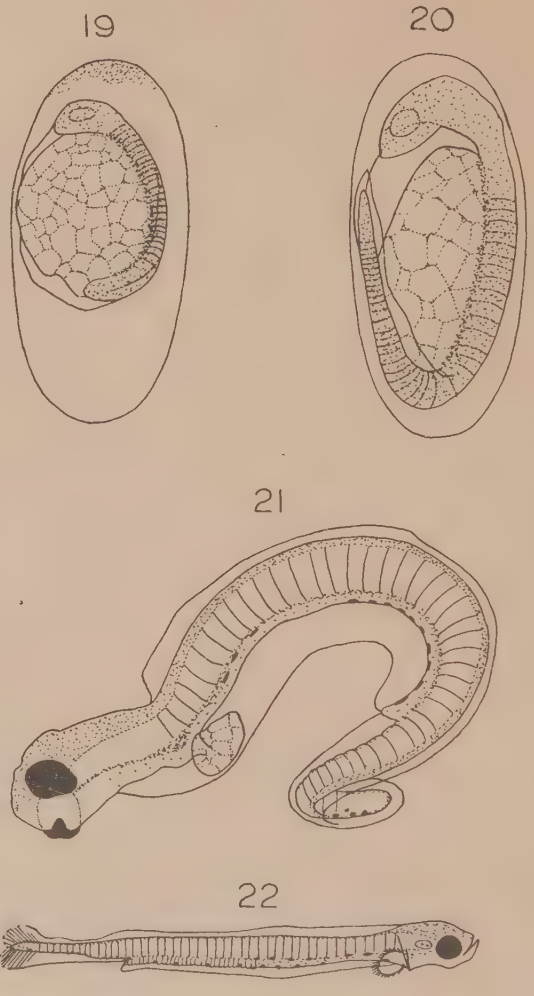


Fig. 18.

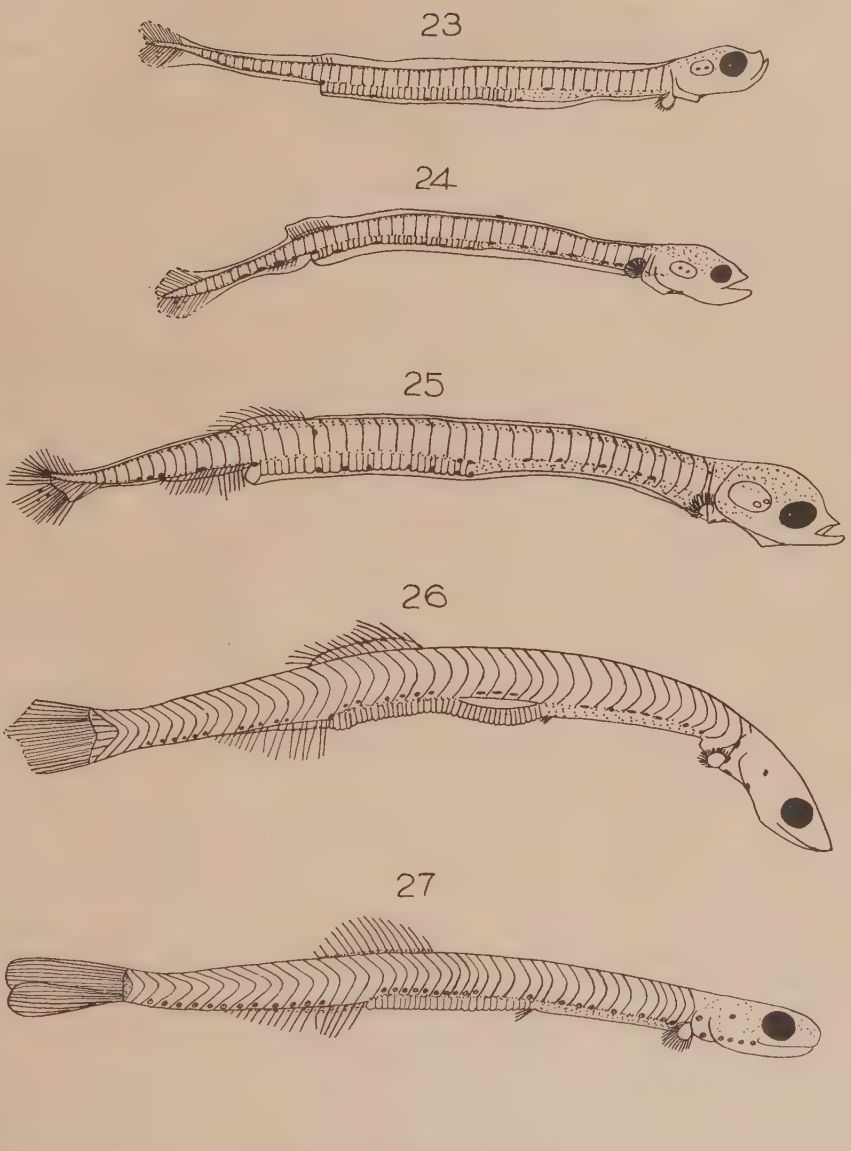
Sketch maps showing comparative quantitative distribution of marsy larvae taken in horizontal hauls, at the surface, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.



Figs. 19-22.

Development stages of the anchovy.

Figs. 19,20. Eggs from Station 44/38, taken in N70.
Fig. 21. Larva from Station 107/38, taken in N70. Length 2.9 mm.
Fig. 22. Larva from Station 98/39, taken in N70. Length 3.6 mm.



Figs. 23-27.

Development stages of the anchovy (Contd.)

Fig. 23. Larva from Station 98/39, taken in N70. Length 4.2 mm.
Fig. 24. Larva from Station 98/39, taken in N70. Length 5.5 mm.
Fig. 25. Larva from Station 98/39, taken in N70. Length 8.5 mm.
Fig. 26. Larva from Station 98/39, taken in N70. Length 18.0 mm.
Fig. 27. Larva from Station 98/39, taken in N70. Length 26.0 mm.

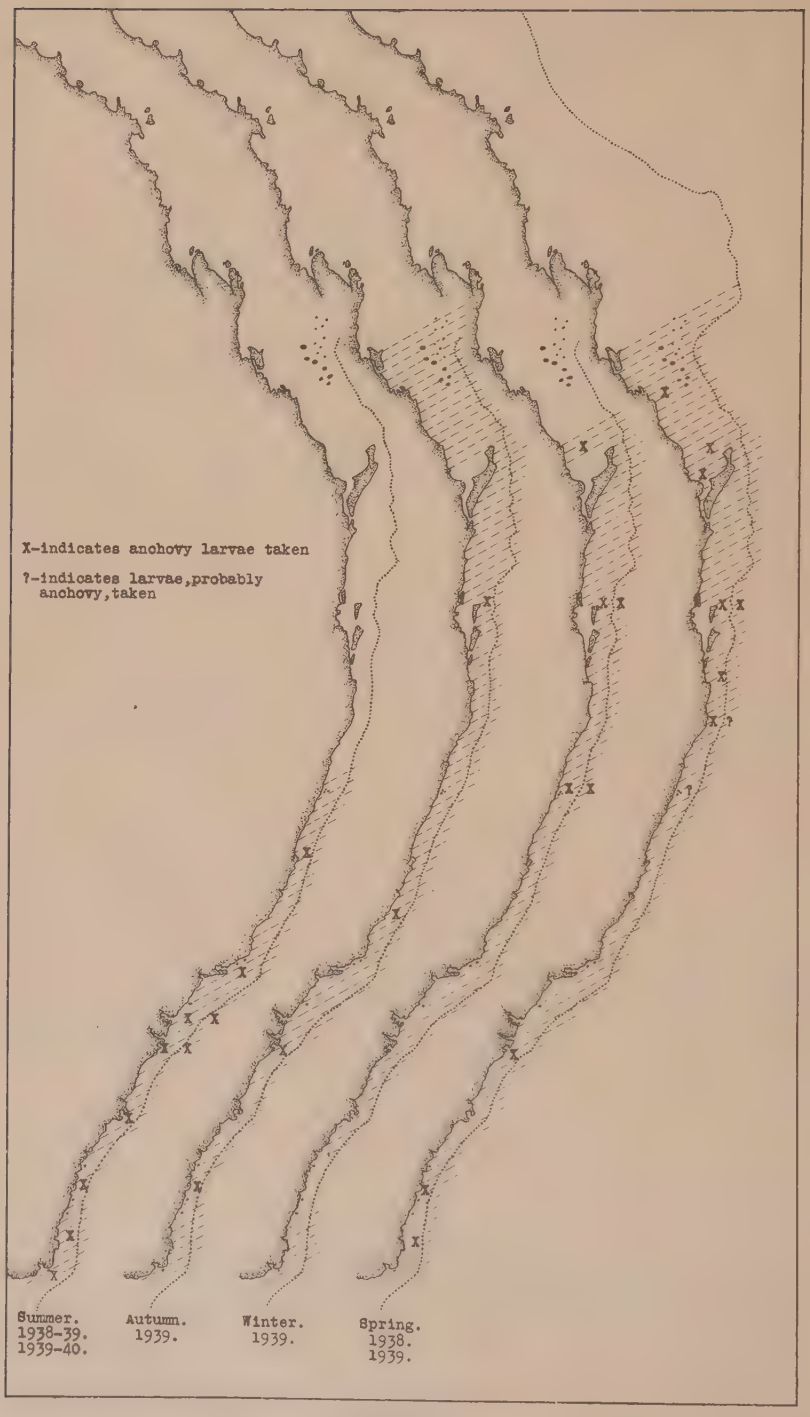


Fig. 28.

Sketch maps showing all localities in which anchovy larvae were taken in oblique or horizontal hauls, at any depth, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

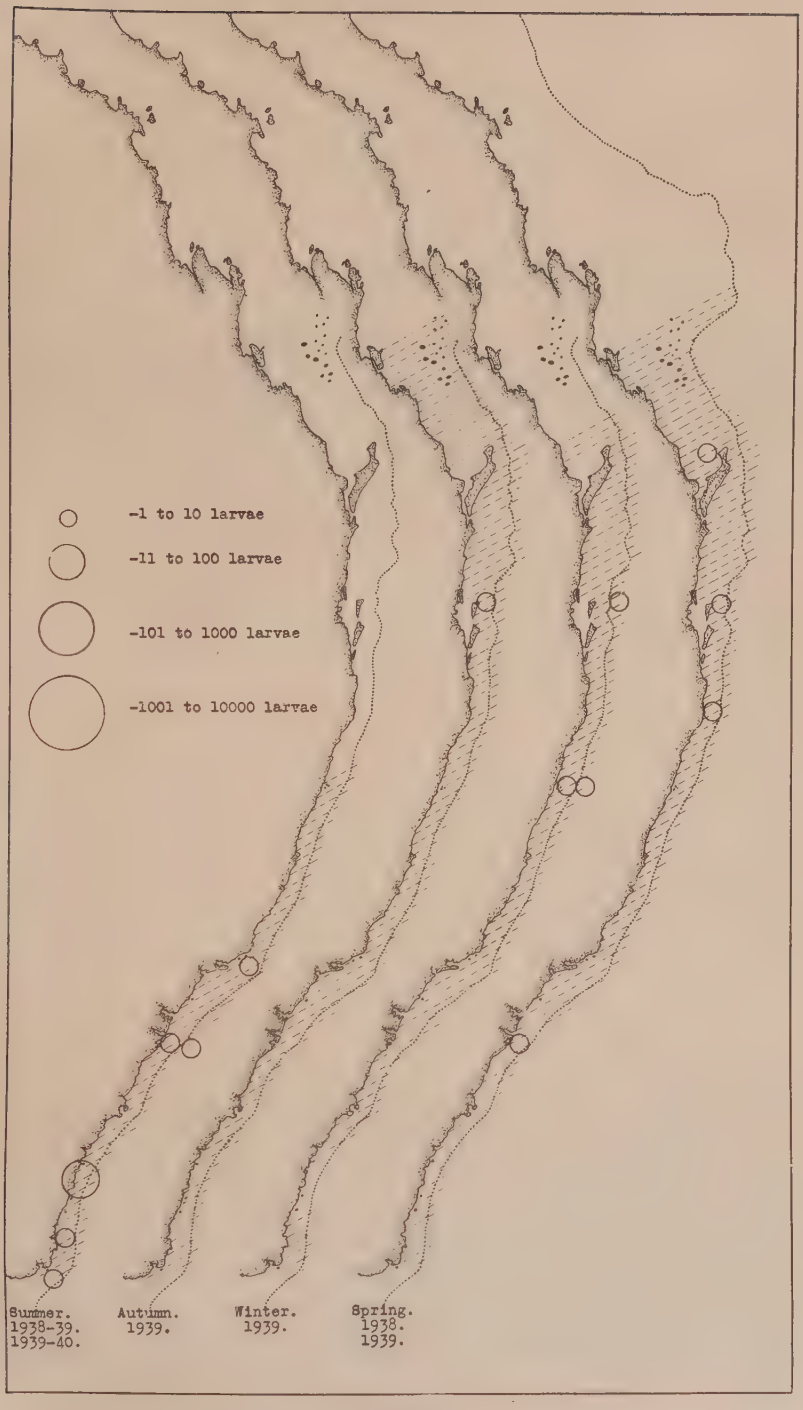


Fig. 29.

Sketch maps showing comparative quantitative distribution of anchovy larvae taken in horizontal hauls, at the surface, of stramin plankton-nets in the waters of New South Wales and Queensland during the four seasons. Stippled areas indicate waters in which hauls were made.

PLATE.

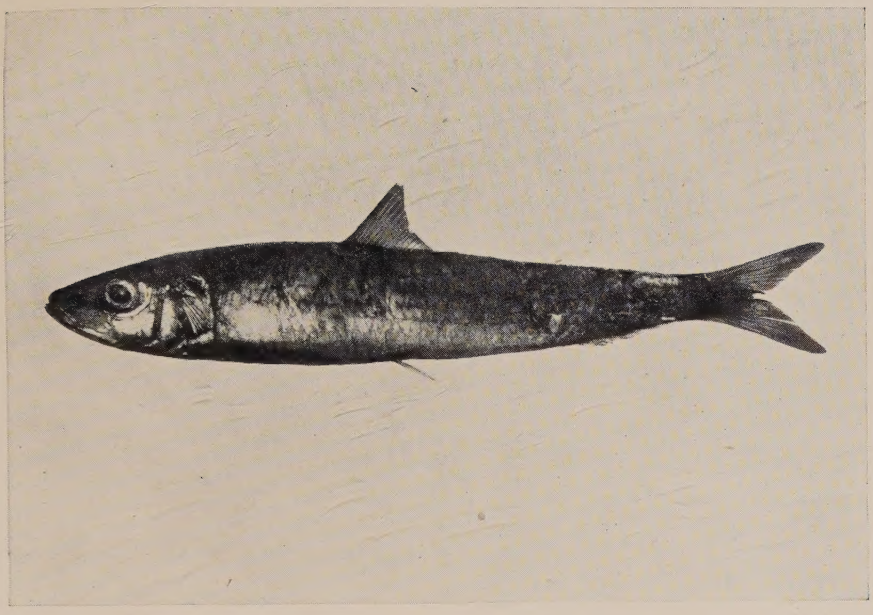


FIG. 1 (*above*).—The Australian pilchard (*Sardinops neophilchardus*). Note characteristic striations on operculum (gill cover), and spots on side.

FIG. 2 (*below*).—Typical pilchard shoal. Northern coast of New South Wales, August, 1939.

C.15889/40.—7

The following list gives the

BULLETINS

numbered from 50 onwards.

A full list of the Council's publications is issued as a Supplement to the Council's Journal for February each year.

50. The Poisonous Action of Ingested Saponins
51. A Soil Survey of the Swamps of the Lower Murray River
52. The Soils of Australia in Relation to Vegetation and Climate
53. The Flying Fox (Pteropus) in Australia
54. Investigations on "Spotted Wilt" of Tomatoes.—II.
55. The Basal (Standard) Metabolism of the Australian Merino Sheep
56. A Soil Survey of Blocks A, B, C, D, and F, Renmark Irrigation District, South Australia
57. Infectious Entero-toxaemia (the so-called Brexy-like Disease) of Sheep in Western Australia
58. The Life Cycle of Stephanurus dentatus Deising, 1839; The Kidney Worm of Pigs
59. Radio Research Board: Report No. 2
60. Radio Research Board: Report No. 3
61. Studies in the Supplementary Feeding of Merino Sheep for Wool Production.—I.
62. A Soil Survey of the Cadell Irrigation Area and New Era, South Australia
63. Radio Research Board: Report No. 4
64. The Ripening and Transport of Bananas in Australia
65. Downy Mildew (Blue Mould) of Tobacco in Australia
66. The Influence of Growth Stage and Frequency of Cutting on the Yield and Composition of a Perennial Grass—Phalaris tuberosa
67. Methods for the Identification of Coloured Woods of the Genus Eucalyptus
68. Radio Research Board: Report No. 5. Atmospherics in Australia.—I.
69. An Investigation of the Taxonomic and Agricultural Characters of the Danthonia Group
70. A Soil Survey of King Island
71. Investigations on Irrigated Pastures
72. Varieties of Wheat in Australia
73. A Soil Survey of the Nyah, Tresco, Tresco West, Kangaroo Lake (Vic.), and Goodnight (N.S.W.) Settlements
74. Observations on Soil Moisture and Water Tables in an Irrigated Soil at Griffith, N.S.W.
75. Nigrospora Musae n.sp. and its Connexion with "Squirter" Disease in Bananas
76. A Soil Survey of the Hundreds of Laffer and Willalooka, South Australia
77. Studies on the Phosphorus Requirements of Sheep.—I.
78. Methods for the Identification of the Light-coloured Woods of the Genus Eucalyptus
79. The "Lucerne Flea" Smynthurus viridis L. (Collembola) in Australia
80. The Establishment, Persistency, and Productivity of Selected Pasture Species on an Irrigated Reclaimed Swamp
81. A Comparative Study of Lolium perenne and Phalaris tuberosa at Varying Stages of Growth
82. The Insect Inhabitants of Carrion: A Study in Animal Ecology
83. Natural Pastures: Their Response to Superphosphate
84. The Basal (Standard) Metabolism of the Australian Merino Sheep.—II.
85. Studies on the Phosphorus Requirements of Sheep.—II. *(Out of print)*
86. A Soil Survey of the Berri, Cobdogla, Kingston, and Moorook Irrigation Areas, and of the Lyrup Village District, South Australia
87. Radio Research Board: Report No. 6
88. Radio Research Board: Report No. 7
89. Radio Research Board: Report No. 8
90. The Identification of the Principal Commercial Australian Timbers other than Eucalypts
91. Further Investigations into the Transport of Bananas in Australia
92. The Apple-growing Soils of Tasmania. Part 1: A General Investigation of the Soils. Part 2: A Soil Survey of Part of the Huonville District

BULLETINS—*continued*

93. Studies on Contagious Pleuro-Pneumonia of Cattle.—I.
94. Fertility in Sheep: Artificial Production of Seminal Ejaculation and the Characters of the Spermatozoa contained therein
95. Radio Research Board: Report No. 9
96. Observations on Myxomatosis Cuniculi (Sanarelli) made with a View to the Use of the Virus in the Control of Rabbit Plagues
97. Studies on Contagious Pleuro-pneumonia of Cattle.—II., II.(a), II.(b), III.
98. Cercospora Leaf-Spot (Frogeye) of Tobacco in Queensland
99. A Survey of the Pastures of Australia
100. Radio Research Board: Report No. 10
101. Radio Research Board: Report No. 11.
102. Studies of Selected Pasture Grasses: The Measurement of the Xerophitism of any Species
103. Wojnowicia graminis (McAlp.) Sacc. and D. Sacc. in Relation to Foot Rot of Wheat in Australia
104. Investigations on the Occurrence and Inheritance of the Grass Clump Character in Crosses between Varieties of Triticum vulgare (Vill.)
105. Investigations on the Associated Growth of Herbage Plants
106. Investigations on "Spotted Wilt" of Tomatoes.—III. Infection in Field Plots
107. A Soil Survey of the Coomealla, Wentworth (Curlwaa), and Pomona Irrigation Settlements, N.S.W.
108. The Basaltic Soils of Northern Tasmania
109. The Variability of Plant Density in Fields of Wheat and its Effect on Yield
110. Radio Research Board: Report No. 12
111. Radio Research Board: Report No. 13
112. Studies in Fertility of Sheep
113. Studies on Coast Disease of Sheep in South Australia
114. The Wood Structure of some Australian Rutaceae with Methods for their Identification
115. A Soil Survey of Part of the Denmark Estate, Western Australia
116. The Relation of Phosphate to the Development of Seeded Pasture on Podsolised Sand
117. The Regional and Seasonal Incidence of Grasshopper Plagues in Australia
118. A Soil Survey of the Horticultural Soils in the Murrumbidgee Irrigation Areas, N.S.W.
119. The Wood Structure of some Australian Cunoniaceae with Methods for their Identification
120. Some Effects of Green Manuring on Citrus Trees and on the Soil
121. Observations on the Toxicity of Fluorine for Sheep
122. The Establishment of Pastures on Deep Sands in the Upper South-East of South Australia
123. A Soil Survey of the Merbein Irrigation District, Victoria
124. The Wood Anatomy of Some Australian Meliaceae with Methods for their Identification
125. A Soil Survey of Part of the Kerang Irrigation District, Victoria
126. Investigations on Chilled Beef. Part I.—Microbial Contamination Acquired in the Meatworks
127. Radio Research Board: Report No. 14
128. An Investigation of the Problems of Salt Accumulation on a Mallee Soil in the Murray Valley Irrigation Area
129. Investigations on Chilled Beef. Part II.—Cooling and Storage in the Meatworks
130. Chemical Investigations on the Fleece of Sheep
131. Black End and Anthracnose of the Banana with Special Reference to Gloeosporium musarum Cke. and Mass.
132. The Wood Anatomy of Some Australian Lauraceae with Methods for their Identification
133. A Soil Survey of the Mildura Irrigation Settlement, Victoria
134. Studies on Bovine Mastitis. I.—Study of an Experimental Herd
135. Investigations on the Storage of Jonathan Apples grown in Victoria
136. Experimental Studies of Ephemeral Fever in Australian Cattle
137. A Soil Survey of the Red Cliffs Irrigation District, Victoria
138. The Economic Biology of Some Australian Clupeoid Fish